EGYPTIAN SCIENCE

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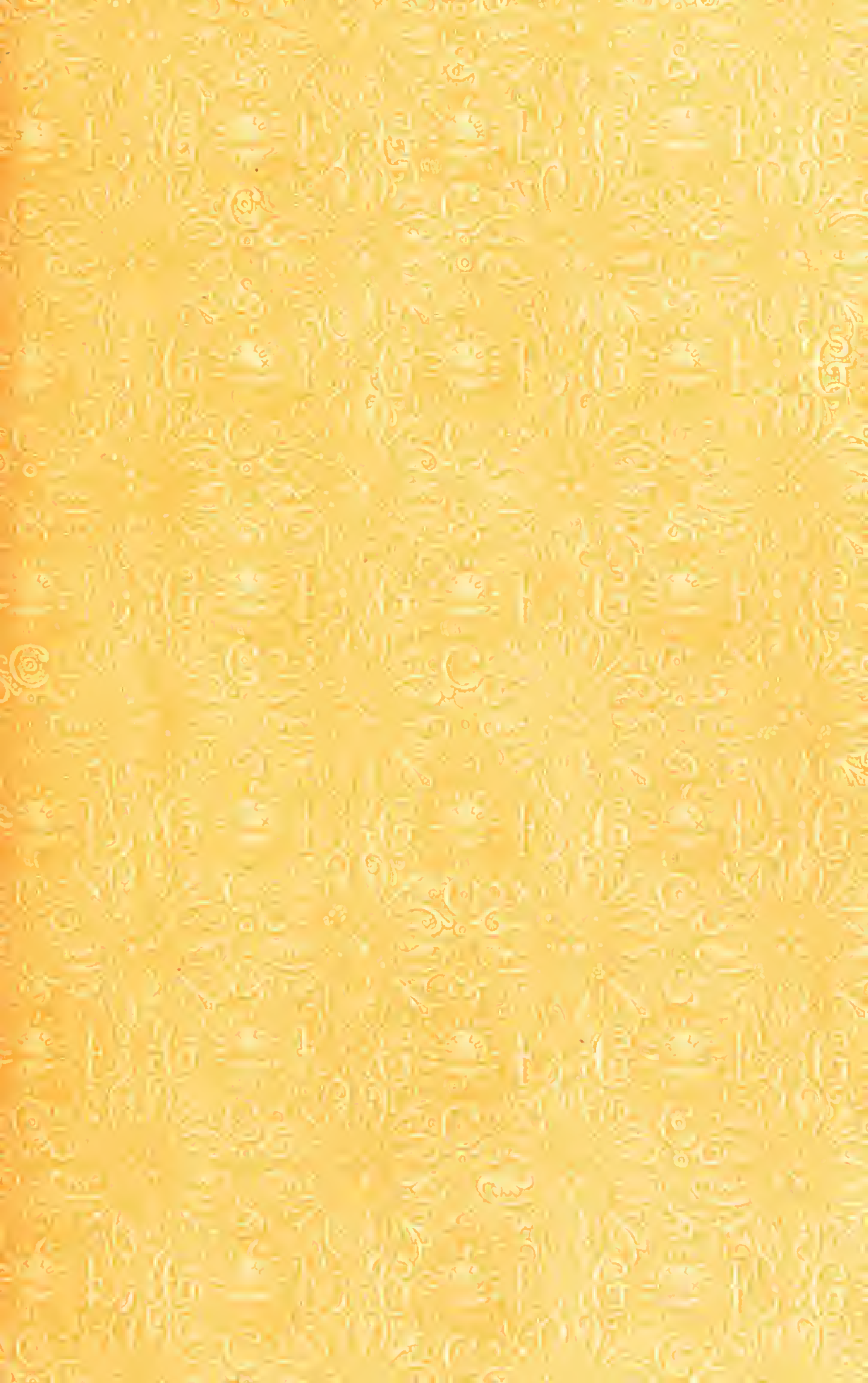

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EGYPTIAN SCIENCE

FROM THE

Monuments and Ancient Books

TREATED AS A GENERAL INTRODUCTION TO THE HISTORY OF SCIENCE

BY

V. E. JOHNSON, B.A.

MAGDALENE COLLEGE, CAMBRIDGE

AUTHOR OF 'CHALDEAN SCIENCE; OR, "OUR DEBT TO THE PAST,"' 'THE USES AND TRIUMPHS OF MATHEMATICS,' ETC.

> 'I shall now speak at greater length of Egypt, as it contains more wonders than any other land, and is pre-eminent above all countries in the world for works that one can hardly describe.'—*Herodotus* (456 B.C)

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TO MY MOTHER.

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PREFACE.

FROM the time when the ancient Greeks first visited the soil of the Pharaohs, the land of Egypt has, almost exclusively, enjoyed the reputation of being the cradle of the Arts and Sciences. To what extent the Egyptians of old time can claim to be the originators of the latter, and the amount of knowledge possessed by them thereof, it is my object to show in this volume, in which I have endeavoured to answer the following questions :—

1. What was the *amount* of scientific

knowledge possessed by the Egyptians?

2. What were the *means* whereby they, or others, as the case may be, acquired this knowledge?
3. Was this knowledge, small or great, whichever it was, entirely of their own acquisition?

I have treated the subject in the light of a general introduction to the study of the *History of Science*—that history which is being daily perceived more and more as being the true history of mankind, and not that history which treats of the reigns and lives of kings or queens, or even the rise and fall of empires, but that history which tells us of man's endeavour after TRUTH—after knowledge—things far more worthy of narration and remembrance than the names of rulers or governors, the victories and craft of generals and statesmen, which so many people even now imagine to be history; but which is but *one*, and that but a very small, part of that history, which should be master of—

'. . . The sphere[1]
Of the seven stars and the solar year,
Of Cæsar's hand and Plato's brain,
Of Lord Christ's heart, and Shakespeare's strain.'

'I have often thought,' said Lord Salisbury, in an address to the Institute of Electrical Engineers, 'that if history were more philosophically written, instead of being divided according to the domination of particular dynasties, or the supremacy of particular races, it would be cut off into compartments indicated by the influence of particular discoveries on the destinies of mankind. Speaking only of these modern times, you have an epoch marked off by the discovery of gunpowder, an epoch marked by the discovery of the printing press, an epoch marked by the discovery of the steam engine; and these discoveries have had an influence infinitely more powerful, not only on the large active destinies, but on the daily life and experience of multitudes of human beings, than even the careers of the greatest conquerors, or devices of the greatest statesmen.'

---

[1] Emerson, R. W.

The discoveries, and their influence upon mankind, with which we are here concerned, are his *first*, and therefore, in some respects, his most interesting achievements in his never-ceasing endeavour to solve the problem of the unknowable.

I take this opportunity of rendering my best thanks to the Venerable Archdeacon Farrar, Professor Max Muller and W. Welsh, Esq., M.A., of Jesus College, Cambridge, for their kind tokens of encouragement in connection with my 'Chaldean Science.' And, above all, I must acknowledge my deep indebtedness to Professors Tyndall and Sayce for their kind words of praise and commendation.

Should this little volume enable the reader to obtain, if only in a small degree, a clearer view of the respective labours and discoveries of the ancients, the time and labour expended in its production will be amply repaid.

V. E. JOHNSON.

LOWER HILL HOUSE, WISBECH,
September 1891.

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PART I.

‘From Egypt, it now appears, were derived the prototypes of the Greek architectural orders, and even their ornaments and conventional designs. Thence came the model of the Greek and Etruscan vases ; thence came many of the ante-Homeric legends—the accusation of the dead, the trial before the judges of hell; the reward and punishment of every man . . . the dog Cerberus, the Stygian stream, the Lake of Oblivion, the piece of money, Charon and his boat, the Fields of Aahlu or Elysium, and the islands of the blessed ; thence came the first ritual for the dead, litanies to the sun, and painted or illuminated vessels ; thence came the dogma of the queen of heaven. What other country can offer such noble and enduring edifices to the gods—temples with avenues of sphinxes; massive pylons, adorned with obelisks in front, which even imperial Rome and modern Paris have not thought it beneath them to appropriate ; porticoes and halls of columns, on which were carved the portraits of kings and effigies of the gods?’—J. W. Draper.

EGYPTIAN SCIENCE.

INTRODUCTORY.

> 'I have heard it said that, in the neighbourhood of Naucratis, a town of Egypt, there existed one of the most ancient gods of this country, named Theuth, who invented the numbers, ciphering, geometry, astronomy, the games of chess and dice, and writing.'—PLATO.

§ 1. 'THEY' (*i.e.*, the ancient Egyptian priests), says Diodorus, 'applied themselves much to the study of geometry and arithmetic. The Nile, which annually changed the aspect of the country, gave rise to numerous lawsuits amongst neighbours, with regard to the boundaries of their possessions. These lawsuits would have been interminable without the intervention of the science of geometry; their arithmetic was useful in the administration of private affairs and in geometrical speculations. . . . In predicting to men the future, their astrologers (or astronomers, for they were originally the same) often predict correctly; they predict dearth as frequently as plenty; epidemics and diseases of the flocks. Earthquakes, inundations, the apparition of comets, and many other phenomena which the unlearned are not able to learn in advance, they predict, after observations continued for a long space of time.' The author of the 'Platonic Epinomis' says that Egypt and Assyria produced the earliest astronomers. Tatian, a Christian writer of the second century, attributed the invention of geometry to the Egyptians. Clement of Alexandria (300 A.D.) mentions the Egyptians and also the Chaldeans as the originators of astronomy. Achilles Tatian declares that the ancient Egyptians were reported to be the first who measured the heavens as well as the earth. Diogenes Laertius states that they were the inventors of astronomy, geometry and arithmetic. Strabo, Herodotus, Aristotle, etc., all assign the origin of geometry to the ancient Egyptians. Herodotus, Homer, etc., have all praised the skill of the Egyptian physicians. These and other statements of the classical writers, coupled with the reports of travellers who have visited Egypt and beheld the vast and mighty ruins of her Temples, her Tombs, and her Pyramids, which seem to fear not even the destroying hand of time, have all tended to confer upon ancient Egypt and the Egyptians an almost inconceivable greatness—a greatness which, mighty though she indeed was, is entirely out of keeping with the researches of modern Egyptologists. In some respects, with regard to 'Engineering,' for instance, Egypt was and still is unsurpassed. But in most of the arts and sciences we have far surpassed her. Her arts and sciences are, however, the foundation of our own, and that is why a study of them is so full of meaning and instruction for ourselves. And though we shall often meet with statements, seemingly to us, perhaps, somewhat childish, and theories erroneous and often absurd, yet, on the whole, I think we shall—even after the foregoing statements of Diodorus—read with feelings of surprise, and oftentimes of profound admiration, of works difficult of execution even in our day, and therefore how much the more so five thousand years ago.

§ 2. It is only within the last quarter of a century that we have been able (owing to the recent decipherment of papyri and the more accurate observations of scholars and travellers) to separate fiction from fact—the story of the romancer from the accurately reasoned narrative of the scholar—with regard to Egypt's ancient greatness. Thus our story, though relating to ancient times, is in one sense a recent one, and should, on that account, possess all the more attraction for the reader.

§ 3. Egyptology, like the rest of the modern sciences, does not remain at a standstill, but is ever growing and increasing. We already know probably far more concerning the manners and customs, the arts and sciences of the ancient Egyptians than ever Herodotus or Diodorus did; and every year—nay, almost every month—brings to light some fresh discovery. Ancient Egypt is by no means marked 'complete.' And the reader is asked to bear this carefully in mind in reading the following pages, which are founded upon—

First. The monuments and books of the Egyptians.

Second. The works of ancient historians, philosophers, travellers, mathematicians, etc., such as Herodotus, Diodorus, Plato, Thales, Pythagorus, etc., etc.

Third. And without which number one would be a sealed book, the researches of modern scholars, travellers, historians and Egyptologists, whose genius and labours have so successfully deciphered the Egyptian hieroglyphics of the past, which were for more than fifteen hundred years undeciphered and unknown.

As number *one* becomes more and more known, fresh light may be thrown upon many facts now obscure and unknown, revealing new pages in the history of Egyptian science. Whether this be so or not (and for my own part, I am compelled to say that I think it will *not*), it would—unless some very extraordinary discovery, indeed, were brought to light—seriously affect neither the facts nor theories contained in this work, in which I have made no statements unsupported by evidence, nor advanced any pet theories of my own. On such a subject, where reliable and precise knowledge is so often lacking, one might speculate until one had produced an Encyclopædia as extended as that of Aristotle. All that we know is able to be stated in a few pages, and to that I have confined myself here, and this must of necessity be the case when the documents are wanting. We know far more of the religion, the arts, architecture, and the manners and customs of the ancient Egyptians than we do about their sciences; but even these present immense gaps. With regard to their architecture, for instance, there exists a period of a thousand years, concerning which we know very little; and with regard to portions of their architecture, that relating most notably to their houses and palaces, there exists scarcely a vestige. In fact, that which ancient Egypt has left us during a civilisation of probably far more than five thousand years is capable of being presented in a single volume.

§ 4. This is not, however, because the ancient Egyptians produced little. On the contrary, it is easy to show that, were we able to enter into all the details of their knowledge, not a single volume, but a work as extended as some modern Encyclopædias would be necessary to expose them. The reasons which permit us to make this statement are very simple—as simple as they are interesting. All that remains to us of the sciences of the ancient Egyptians is contained in a *very* few papyri or books setting forth elementary notions, and which served (according to some) for instruction in elementary schools. Now, although the foregoing statement may be questioned, yet if we judge of these sciences by their *applications*, we at once perceive that some of them, at any rate, were in many respects really very advanced. All that we know concerning ancient Egyptian geometry, for instance, is contained in one single papyrus (which, with the exception of an older leather-roll on some mathematical subject, apparently too stiff to be opened, is the only treatise on mathematics that they have left us), and some few references to the same in later classical writers ; but, judging of this science by the applications which they made of it, we at once perceive that the science of geometry was (empirically, at any rate) certainly developed amongst this ancient people. They knew, in fact, how to measure the surface of the earth, to the evaluation of which frequent references are made in their papyri. They knew also the theory and application of levelling, since they constructed vast artificial lakes and immense canals. They knew, also, in its most minute details, the theory of stone-cutting, as is proved by the combinations in their monuments, and the perfection (scarcely attainable even at the present day) with which they adjusted their joints. They possessed also, from the most remote times, such simple mathematical instruments as the rule, the square, the compass, the mason's level, etc., and also instruments more complicated, such as the circle divided into 360 or 365 degrees. They possessed also, at the time of the building of the Great Pyramid, *i.e.*, more than five thousand years ago, various implements and tools which were regarded, until quite recently (1883), as amongst the latest triumphs of engineering science. These same Pyramids are *oriented* (*i.e.*, their four sides made to face the four cardinal points — north, south, east and west), too, with a greater degree of exactness than even the famous Tycho Brahe (1546-1601) was able to achieve with respect to his own astronomical buildings, with his justly celebrated quadrant at Uranianberg.

We are, again, almost entirely ignorant in detail of the chemical industry of the ancient Egyptians, but we are certain that these operations were both numerous and complicated; for they knew in effect, from the most remote times, how to extract the most important metals, how to manufacture glass, papyrus, perfumes,[1] artificial stones and colours which have remained absolutely unalterable for thousands of years.

§ 5. Now these first indications, imperfect and incomplete though they be, permit us to state that the scientific and industrial knowledge of the ancient Egyptians were, in some respects, at any rate, certainly advanced, and we have, as well, two other sources of information, which permit us to go still further. For, if we behold a people (*like the Greeks*) possessing no scientific knowledge whatever (with the exception of some *very* elementary ideas on the subject of astronomy, derived in all probability from the Chaldeans), and that, too, on their own authority, before having relations with the Egyptians, and possessing this knowledge directly, after these relations have been established, we may confidently state, I think, that the first had borrowed from the second; and if the knowledge of the first has come down to us, we are able, to a certain extent at any rate, to become acquainted with the nature of the borrowed knowledge. Again, if we know of a people (*like the Chaldeans*) who had, from the most remote times, a frequent and close intercourse with the ancient Egyptians, we may, in all probability, gather much supplementary knowledge from the writings of the first with regard to the learning and studies of the second.

---

[1] They have, in fact, never been equalled for their skill in the manufacture of perfumes. Some of their ointment, preserved in an alabaster vase in the Museum of Alnwick, still retains a pungent odour. Its age cannot be less than three thousand years.

§ 6. Thus, while laying most stress on that positive knowledge (alluded to in § 3) contained in their monuments and papyri, I have, in making so to speak the 'Scientific Balance-Sheet of the *ancient* Egyptians, freely availed myself of all that supplementary knowledge to be obtained from (1st) an examination of the scientific *applications* made by them; (2d) The works of the early Greeks, such as Pythagoras, Plato, Thales, Herodotus, Solon, etc., who had relations with them; (3d) Their sometime friends and sometime enemies, the Chaldeans.

§ 7. Our account naturally divides itself into two distinct parts. *First*, science, as known to the Egyptians prior to the time when Psammetik opened the ports of Egypt to Grecian and other strangers. *Secondly*, as known to the Egyptians when the famous Alexandrian school flourished upon the soil of Egypt. That school where Greek and Egyptian worked together, and that is why it is so difficult to assign the work done by each people. Leaving this difficulty to be dealt with in its proper place, let us pass on to our account of the sciences of the ancient Egyptians, which comprised Astronomy, Mathematics, Engineering, Natural Philosophy, Medicine and Chemistry, commencing with Astronomy, that science which is perhaps of all others the grandest, the most ennobling, the most sublime.

THE EGYPTIAN ASTRONOMERS.

'Like the astrologers of old,
In that great vision I beheld
Greater and deeper mysteries.
I saw with its celestial keys,
Its chords of air, its frets of fire,
The Samian's great Æolian lyre,
Rising through all its seven-fold bars,
From earth unto the fixed stars.
And through the dewy atmosphere,
Not only could I see but hear
Its wondrous and harmonious strings,
Its sweet vibration, sphere by sphere;
From Dian's circle light and near,
Onward to vaster, wider wings,
Where chanting through his beard of snows
Majestic, mournful Saturn goes,
And down the sunless realms of space
Reverberates the thunder of his bass.'

Longfellow.

CHAPTER I.

ASTRONOMY.

> 'And still the skies are opened as of old
> To the entranced gaze, ay, nearer far
> And brighter than of yore.'—MORRIS.

§ 1. From a most remote period, anterior to all history, the ancient Egyptians were astronomical observers. This fact is so well attested that the most sceptical of modern historical critics (Sir G. C. Lewis) does not attempt to deny it. What is doubtful, however, what is questioned and what must be allowed to be, to some extent, a matter of conjecture, is their degree of proficiency in this science, and the means whereby this proficiency was attained. First, then, with regard to their progress in the science of astronomy.

§ 2. Let us consider first of all their *general* proficiency in this science. From the most remote antiquity the stars appear to have been mapped out by them into constellations, those which composed the zodiac being carefully distinguished by them. They were acquainted, too, with the length of the month and the year, they had observed eclipses and discovered the planets, or *akhimu-urdu*, distinguishing them from the *akhimu-seki*, or fixed stars, placing in the same category the sun and moon. The names of the planets were as follow :—

Jupiter = Har-tep-sheta.
Saturn = Har-ker-her.
Mars = Harmakhis or Hardesher.
Mercury = Sebek.
Venus = Duau or Bennu.

They were acquainted, also, with the obliquity of the ecliptic to the equator, and were able to determine, in a wonderfully accurate manner, the latitude of a place, and were also acquainted with a method of drawing an *exact* meridian line, of which more later on. Let us now, however, briefly consider five or six of the chief *points* in ancient Egyptian astronomy, concerning which there is no doubt that they engaged a great deal of the attention of these astronomers of old time.

§ 3. It seems now proved beyond a doubt that their attention was given—

(1.) To eclipses of the sun and moon.

(2.) To occultations of the planets.

(3.) To the motions of the planets and the determination of what is known as their periodic and synodic times.

(4.) To the construction of tables of the fixed stars, and the mapping them out into constellations.

(5.) To the settling of the exact length of the solar year.

§ 4. There is no doubt that the ancient Egyptians, from a very remote period indeed, observed eclipses, and entered their occurrence in their papyri or books, wherein all important events were registered. Whether they knew their causes, or registered them scientifically, whether they were able to any extent to predict them, are matters upon which it is at present extremely difficult to come to any definite conclusions. Much doubt is thrown upon the ancient Egyptian registrations in astronomy by the fact that neither Hipparchus, nor Ptolemy, who both lived in Egypt, availed themselves, as far as we know, of the Egyptian records. And, moreover, it is not easy to perceive how the ancient Egyptians, with their very loose ideas on the subject of chronology, could have assigned to their astronomical observations such definite dates as could make them of service to later generations. For, curiously enough, the ancient Egyptians at no time appear to have made use of any era, dating events as they did by the 'regnal reigns of their kings.' In default of any authoritative table of their kings—and none such appear to have existed—a stranger would derive little or no advantage from the statement that a total eclipse of the sun took place (say) in the tenth year of the reign of Rameses II. With regard to the prediction of eclipses, we possess little or no other evidence than the fact that Thales, whom, we know, studied in Egypt, is said to have predicted an eclipse of the sun, which happened certainly in the *year* predicted. But there is nothing in this fact to prove that he derived his knowledge of astronomy from Egypt. It is conceivable, and in fact far more probable, that he derived it from the Chaldeans (the greatest astronomers of antiquity and the teachers of the Egyptians), amongst whom the cycle of 223 lunations, or 18 years 11 days about, which is quite sufficient for the approximate prediction of lunar, and to some extent solar eclipses, was certainly known. Even supposing that the Egyptians were able to foretell lunar, and, to a certain extent, solar eclipses, there is no evidence that this knowledge was of Egyptian growth; in fact, all the evidence tends to show that this knowledge, in common with almost all of the ancient Egyptian astronomy, was of exotic origin.

§ 5. With regard to 'the occultation of planets by the moon,' we have the testimony of Aristotle to support this statement; for he says, after describing an occultation of Mars by the moon, that similar occultations of the stars (*i.e.*, the planets) had been noted by the Egyptians *and Babylonians*, who had observed the heavens for many years, and communicated to the Greeks many oral reports concerning each of the stars. We possess, however, no knowledge to show that they observed these occultations *scientifically*. Such occultations are, we know, of primary importance in the determination of astronomical distances; but, in order to be of any service, they must be very carefully timed, and repeated at several different places. Now, although the ancient Egyptian priests at the various seats of learning—Thebes, Heliopolis and Memphis—did, in all probability, observe these occultations from their different localities, yet we do not hear of them comparing their reports or drawing any conclusions from the recorded differences in their observations; and moreover, we do not know that the ancient Egyptians were able to measure time with any degree of accuracy. The *Sundial* was known to them as early, certainly, as 700 B.C., and probably very much earlier; but sundials are of no use for measuring the time of *lunar* occultations, which are, of course, only observable at night. For this purpose some kind of a clock is necessary, but we have little or no evidence that the ancient Egyptians possessed clocks. The *clepsydra*, or waterclock, was known to their neighbours, the Chaldeans, from a very remote period of antiquity, and may have been used by the ancient Egyptians. However this may be, as far as is at present known, the bare fact of the occultation, together with some rough approximate note of its time, appears to have been all that was recorded; and it does not therefore appear that any materials of value were accumulated thereby, or that any of those important and practical results which modern astronomers derive from an occultation or a transit were attained in any degree, or even apprehended as being so attainable by these Egyptian astronomers of old time.

§ 6. *The motions of the planets*, somehow strangely neglected by the earlier Greek astronomers, which neglect has been accounted for by the fact that the planets, on account of their motion, 'were classed with wandering meteors and comets,' and consequently looked down upon—the admiration of the Greeks being reserved for the stars, as being fixed and immovable — attracted attention in Egypt from very primitive times, and must have been studied with great care, since conclusions not very remote from the truth were arrived at concerning them. Eudoxus,[1] who, it is expressly stated, derived his knowledge of the motions of the planets from the ancient Egyptians, states that the periodic time of Saturn, or the period in which he completes his orbit, was 30 years; the periodic time of Jupiter, 12 years; that of Mars, 2 years; that of Venus and Mercury, like that of the Earth, 1 year. The real times are respectively:—

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[1] 'Eudoxus primus *ab Egypto* hos motus in Græciam transtulit' (Seneca, Nat. Quæst. vii. 3).

	Years.	Days.	Hours.
Saturn, . . .	29	174	1
Jupiter, . . .	11	315	14
Mars, ...	1	321	23
Venus, . . .	—	234	16
Mercury, . . .	—	87	23

Thus, with regard to the three outer planets—Mars, Jupiter and Saturn—the error is very small; while, with regard to Venus and Mercury, the error is considerable. It is possible, however—one might say very probable—from the circumstances of the case, that Eudoxus merely meant that the two inner planets, Venus and Mercury, completed their orbits *within* the space of one year—not that it took the full year to complete them; and this is rendered still more probable from the fact that Eudoxus, in giving his periodic time, in no case intro-

duces any fractions or parts of a year in his tables. It is, however, curiously enough, otherwise with regard to his statements of the 'synodic periods' of the planets, or the times of their periodic conjunction. Here again it is stated that he derived his knowledge from the ancient Egyptians; and his knowledge is, in this case, comparatively speaking, exact and accurate. He gives their 'synodic' periods in months and days. The synodic period of—
Mercury is 110 days.
Venus is 19 months.
Mars is 8 (25?) months and 20 days.
Jupiter and Saturn is almost exactly 13 months.

If the correction (proposed by Ideler, 'Berlin Transactions for 1830,' p. 78) in the case of Mars be accepted, then these numbers give very approximately the periods, as the accompanying table shows.

	Eudoxus' Time.	True Time.	Excess.	Defect.
Saturn, . .	390 days	378 days	$\frac{2}{65}$	—
Jupiter, . .	390 "	399 "	—	$\frac{3}{130}$
Mars, . . .	770 "	780 "	—	$\frac{1}{77}$
Venus, . .	570 "	584 "	—	$\frac{7}{285}$
Mercury, . .	110 "	116 "	—	$\frac{3}{55}$

The error is in no case so much as $\frac{1}{18}$th; and in the case of Mars (if the proposed reading is correct) it is as small as $\frac{1}{77}$th.

§ 7. The Scholiast upon Aratus says that the Greeks derived their knowledge of the fixed stars from the Egyptians and Chaldeans. The distribution or grouping of the fixed stars was the subject of one of the astronomical books assigned to Thoth or Hermes, and required to be learnt by the *horoscopus*, a priest of high rank in Egypt. This grouping included, of course, an arrangement of the constellations through which the sun travelled; *but* this grouping or 'signs of the zodiac' amongst the ancient Egyptians did not correspond with the ordinary 'signs of the zodiac' which the Greeks derived (undoubtedly) from the Chaldeans or Babylonians, and which the later Egyptians of the Alexandrian school borrowed from the Greeks. It was like that 'duodecimal;' but the names of the groups were, for the most part, different.[1]

There is therefore considerable difficulty in interpreting the astronomical monuments of the ancient Egyptians, it being seldom possible to identify the stars mentioned under the obscure and strange nomenclature employed by them.

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[1] Achilles Tatian says that the Greeks and Romans took the name of the balance from the ancient Egyptians.

§ 8. They were perhaps acquainted with the *Precession of the Equinoxes*, since the Chaldeans or Babylonians had made, we know, an empirical discovery of this fact, and the ancient Egyptians had from a most remote period a frequent and close intercourse with these same Chaldeans. The ordinary ancient Egyptian year consisted, like our own, of 365 days, but it was divided differently. It contained 12 months, each of 30 days, after the expiration of which, at the end of the year, 5 days were intercalated. This year seems to have existed from very remote times in ancient Egypt, though it is probable that the ancient Egyptians, in their infancy as a nation, divided their year into 12 lunar months (the moon's revolution round the earth evidently being the origin of this division of the year into months), the 28 years of 'Osiris'' reign being derived, as Plutarch has observed, from the number of days taken by the moon to perform her course round the earth; and it is, moreover, worthy of notice that the ancient Egyptian hieroglyphic, signifying month, was represented by the crescent of the moon, as is abundantly proved from the sculptures and authority of Horapollo. This year is very, *very* remote indeed, however, anterior to all history, for the substitution of the solar or astral year of 365 days in place of the older year of 12 lunar months was amongst the very earliest changes in the Egyptian year. The five *hru*, or 'additional' days, are first mentioned on the monuments of the twelfth dynasty, though their introduction into the calendar probably took place at an earlier period. This 'vague' year continued in common use even as far down as the time of the Ptolemies. At the same time, the more exact year of of 365¼ days was known to the ancient Egyptians from a remote period, and frequent attempts appear to have been made to introduce it into the general calendar—without much success, however, it would appear, for it is very doubtful if a *fixed* year actually came into common use before the final reformation of the calendar by Augustus. All ordinary reckonings were made by means of the year of 365 days; and even their festivals followed it, with the natural result that, in course of time, they circled round the entire course of the seasons, the festivals which were properly summer ones becoming, in time, spring festivals, winter ones, and, as time passed on, autumn ones, till at length they returned to their appointed season, only to go through the same round of changes once more. This resulted, of course, from the omission from the calendar of the quarter day, by which the true solar year was in excess of the year of 365 days, and the neglect of any compensation for it, such as is furnished by the extra days of our 'leap years.' However, this excess, as we have already stated, appears to have been known to the ancient Egyptian whose 'Sothiac Period or Cycle' was founded upon it. This was a period of 1461 'vague' or 1460 'true' years, which was certainly recognised by the later Egyptians, and which is believed to be indicated by some monuments of the Pharaonic time. This period was called *Sothiac*, because the ancient Egyptians fixed its commencement at a date when the Dog

Star, which they called *Sothis*, rose heliacally (*i.e.*, when it first became visible after a period of obscuration in the rays of the sun) on the first day of the month *Thoth*, which was the beginning of the year amongst the ancient Egyptians. Now Sirius, or the Dog Star, rose heliacally in Egypt on the 1st of *Thoth* in the years 2782 and 1322 B.C., and again in 138 A.D. This last-named year was *certainly* known to the Egyptians, as also the year 1322 B.C. Concerning the first (2782 B.C.), the only evidence is that there are grounds for believing that the Sothiac period was both known and used prior to the nineteenth dynasty (1460 B.C. *cir.*), and therefore, if so, they had advanced, even at that remote period of antiquity, so far on the road to accuracy as to know that the solar year consisted of 365¼ days. Any further accuracy does not, however, appear to have been obtained by the ancient Egyptians.

§ 9. It has been conjectured that the ancient Egyptians were acquainted with the *true or Copernican system of the Universe*, and that Pythagoras derived from them his acquaintance with the fact that the sun is the true centre of the planetary system, and the earth a spherical body revolving round it.[1] It is, I think, however, far more probable that he derived his knowledge of these facts from the Chaldeans. The opinions attributed to Pythagoras by Philolaws clearly point to a derivation of his knowledge from these people, who told him that 'the earth and planets move in *oblique circles*[2] about fire.

§ 10. There is no evidence that the ancient Egyptians (like the Chaldeans) were acquainted with the *Phases of Venus*, the *Rings of Saturn*, or the *Satellites of Jupiter*, for there is no evidence that the telescope was known to them. In early times it most certainly was not, as is proved by certain constructions (the boring of a tunnel of immense length into the solid rock) made by the builders of the Pyramid, to take the place of a telescope, for the orientation of the Pyramid. And the age of the Pyramid Builders, although so remote, appears to have been the time at which Egyptian science attained its culminating point. Nor is there any evidence that the ancient Egyptians were acquainted with the nature of *gravity.* And as we have already observed, it is not easy to see how the ancient Egyptians, with their loose ideas on the subject of chronology, could assign to their astronomical observations such definite *dates* as should render them of service to later generations.

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[1] (Kepler) on the discovery of his famous 'Laws,' exclaimed that 'he had stolen the golden vases of the Egyptians to build up a tabernacle for his God far from the confines of Egypt.'

[2] This phrase, 'oblique circles,' clearly shows that they (*i.e.*, the Chaldeans) were acquainted as well with the 'ellipticity, of the planetary orbits.

§ 11. 'Astronomy with the Egyptians,' says Brugsch, 'was not that mathematical science which calculates the movements of the stars through the construction of grand systems of the heavens. It was rather a collection of the observations which they had made on the periodically occurring phenomena of earth and sky in Egypt, the bearings of which upon each other could not long have escaped the notice of the priests, who, in the clear Egyptian nights, observed the brilliant luminaries of their firmament. Their astronomical knowledge was founded on the base of empiricism, not on that of mathematical science.'

§ 12. This is no doubt true, but it must be borne in mind that practical and observational astronomy must come first to render theoretical and mathematical astronomy possible. And there is this to be said for the astronomy of the ancient Egyptians, that it does not appear to have been so tainted with *astrology* as that of most ancient nations. In their calendar, certain days were reckoned as lucky or unlucky in connection with stellar influences, and horoscopes were sometimes cast for certain individuals from the general aspect of the stars at their birth, and from the then supposed influence of certain ruling constellations. But astrology did not hold that place in ancient Egyptian astronomy that it did in that of the Chaldeans, from whence it was undoubtedly derived. It does not, in fact, appear to have been held in much repute in Egypt, for a very small portion of their now existing literature treats of this subject, and the references made to its employment by them in the works of the classical writers are few and scanty.[1]

§ 13. Such was ancient Egyptian astronomy. It might have been something very different, for it was given to these old Egyp-

Note.—The Egyptians appear to have divided the day into four parts, each part bearing the name of a star.

[1] Herodotus, ii. 82, does not necessarily bear on the subject.

tians—had they but taken the opportunity—not only of becoming the most famous astronomers of antiquity, but perhaps of all the coming ages. This apparent paradox will become clearer after a perusal of the following paragraphs.

ASTRONOMICAL INSTRUMENTS AND OBSERVATORIES.

THE GREAT PYRAMID.

> ‘Beside the eternal Nile
> The Pyramids have risen.’
> SHELLEY—*Queen Mab.*

§ 14. An elaborate and careful examination of the famous Pyramids of Ghizeh by both English and foreign *savants*, and more particularly of the actual relations presented by the Great Pyramid—its geographical position, dimensions, shape, internal structure, etc.—has very forcibly suggested that *the builders of this Pyramid* were ‘ingenious mathematicians, who had made some progress in astronomy, though not so much as they had made in the mastery of mechanical and scientific difficulties.’

§ 15. In the foregoing paragraph, the reader will have no doubt noticed that the words 'builders of this Pyramid' are italicised, and that I do not say 'the *Egyptians* who built this Pyramid,' etc. I have done this because all the evidence from the circumstances connected with the religion of the pyramid-kings, and all that we are able to learn respecting this matter from Manethon and Herodotus, and all the astronomical evidence given by the pyramids themselves, tend to suggest that the builders of the pyramids of Ghizeh (or, at any rate, of the 'Great Pyramid,' the only one with which we are concerned), so far as their astronomical and mathematical relations, at all events, were concerned, were Chaldeans.[1] Such being the case, we cannot, of course, infer that the ancient Egyptians were acquainted with *all* that mathematical and astronomical knowledge which an examination of the Great Pyramid has shown must of necessity have been known to the builders thereof. *Some* of this knowledge must, from the very nature of the case, have been known to them, and as the work progressed, very much more, perhaps. Whether

[1] See R. A. Proctor's 'Great Pyramid,' ch. I.

this be so or not, the subject is one of such deep interest and importance that I have ventured to introduce it here, telling us, as it does, so much about the scientific and mechanical knowledge of the ancients.

§ 16. An examination of the various relations actually presented by the Great Pyramid, and all that the classical writers on the subject have told us concerning its construction and uses, have revealed to us the following facts, all of which the reader will find fully discussed in Proctor's 'Great Pyramid' (Longmans, Green & Co.), and the details of which need not detain us here:—

First. Its builders supposed the heavens to be spherical, and the earth itself a sphere.

Secondly. They were able, by observations of the circumpolar star, *Tuban* (the Dragon), to ascertain the latitude of a place with a remarkable degree of exactness, considering the fact that they were unacquainted with the influence of refraction on the heavenly bodies.[1]

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[1] Their desire appears to have been to place the Great Pyramid in latitude 30°. Now, the centre of the Great Pyramid's base lies about one mile and a third *south* of this latitude, and, taking into account their ignorance of refraction, they were only *half a mile* out, as half a mile farther south would make the pole *seem* just right.

Thirdly. They were able—by observation of circumpolar stars, and the boring of an immense tunnel 350 *feet* long through the solid rock on which the pyramid is built—to *orient*, *i.e.*, make the four sides of the pyramid face the four cardinal points, north, south, east and west, with an accuracy such as no modern could surpass without the use of a telescope, and which *does* surpass the orientation achieved by the famous Tycho Brahe, with his justly celebrated Quadrant of Uranienberg.

Fourthly. To measure a degree of latitude with an amount of accuracy far surpassing any other ancient endeavours, and which, considering the instruments at their command, is truly most remarkable.

So far had the astronomy of the builders of the pyramids progressed, even at this early period in the world's history—more than five thousand years ago. The incalculable aid to the progress of astronomy which might have been effected by means of the Great Pyramid, left in that unfinished state mentioned by Proclus when he says that it terminated above in a platform, *i.e.*, before the outer casing was put on, and the pyramid 'capped,' so to speak, was not known to the ancients; for centuries would have been required to elapse to reap even a tithe of that knowledge, and such observations were limited to some 20, 30, or at most some 50 years. 'I could descant,' says R. A. Proctor, 'at great length on the value which the Great Pyramid [when in the condition alluded to by Proclus] . . . must have had for astronomical observation. I could show how much more exactly than by the use of any gnomon the sun's annual course around the celestial sphere could be determined by observations made from the great gallery, by noting the shadows of the edges of the upper opening of the gallery on the sides, the floor, and the upper surface of the ramps.[1] The moon's monthly path and its changes could have been dealt with in the same effective way. The geocentric paths, and thence the true paths of the planets, could be determined very accurately by combining the use of tubes, or ring-carrying rods, with the direction-lines determined from the gallery's sides, floor, etc. The place of every visible star along the zodiac

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[1] See his 'Great Pyramid,' frontispiece and]figure 12.

(astrologically the most important part of the stellar-heavens) could be most accurately determined. Had the pyramid been left in that incomplete, but, astronomically, most perfect form, the edifice might have remained for thousands of years the most important astronomical structure in the world. Nay, to this very day it would have retained its pre-eminence, provided, of course, that its advantages over other buildings had been duly supplemented by modern instrumental and optical improvements.'

This huge edifice was, however, unfortunately erected for an entirely selfish purpose—the self-glorification of Cheops—both as regards a tomb and an *astrological* observatory, and the immortal service which this edifice might have rendered to the progress of science and of truth was overlooked by them, and the growth of astronomy thereby incalculably retarded. It was given to these Egyptians of old time to have been the foremost astronomers of that—or, indeed, probably any—age; but they let the opportunity pass by, never to return. Such want of foresight is not without its lessons to ourselves.

Amongst the instruments used by the ancient Egyptians in astronomy was the *Gnomon*, a straight rod placed vertically upright on a levelled piece of ground or smoothed stone platform. The *Sundial* and *Clepsydra*, or waterclock, also appear to have been used by them in later times. *Astrolabes* of various forms were also used by them, and a circle divided into 360 or 365 equal parts or degrees has been found on one of the tombs of their kings; and such devices and instruments as Ferguson, the self-taught Scotch peasant-astronomer, used to determine the position of the heavenly bodies, would be likely to occur to and be employed by the ancient Egyptians. Their astronomical instrument *par excellence* was, of course, the Great Pyramid at Ghizeh.

§ 17. Let us turn now to the origin and early days of astronomy. It is an inquiry which has an especial interest of its own. I do not know of any other so well suited to commend to the reader's attention the movements of the heavenly bodies, which, as Carlyle has, I believe, remarked, though taking place all the time around us, are not half known to most of us.[1] It has been remarked that:—'As civilisation progresses, the proportion of persons acquainted with the motions of the heavenly bodies becomes less and less.' And this sad fact is, alas, only too true. At the present day, if a student of astronomy sets up an observatory, he is more likely to forget what he already knows about ordinary astronomical phenomena than to pay closer attention to them. To such a state of perfection has the mechanical part of the science of astronomy been brought, that if he desires to observe a particular planet or star, strange as it may seem, the last place almost that he will turn to is the starry sky; he merely sets the circles of his telescope aright, knowing that the planet or star he desires to observe will be in the field of view. He as often as not does not turn his telescope to the object before the door of the revolving dome of his observatory has been opened—that is, while no part of the heavens is in view. Artificial time-measures having come more and more into use, and fewer persons being engaged out of doors during night-time under conditions making the movements of the starry heavens worth observing, have also been powerful factors in this decay of the study of the movements of the heavenly bodies which encircle us on all sides. That this is a fact to be regretted but few, I think, will venture to deny. And, again, what can be more interesting than an account of man's *first* discoveries in his endeavour to solve the mystery of the stars? The method of inquiry adopted in our account of the evolution of astronomy is an *a priori* one, which is, I think I may say, the most interesting as well as the most likely to lead to correct results in an inquiry of this kind. For if we place ourselves mentally in the position of the shepherds and tillers of the soil in olden times, we are able to tell precisely what they were likely to notice, in what order and in what way. For we know exactly how the heavens appeared to men in ancient times; should the occasion arise, the astronomer of to-day can readily determine the exact appearance of the heavens at any given place and time. We now know, thanks to the discoveries of modern pre-historic research, the conditions under which man's first observations of the heavenly bodies must have been made; and we can, therefore, not unsafely infer what particular celestial objects first engaged his attention, what difficulties presented themselves as time proceeded; and how such difficulties were successively overcome. To those who have paid but little attention to the subject of astronomy, its truths, its predictions, its revelations are most astonishing, and but for their rigorous verification, would be absolutely incredible; and it is only when we remember that, from the very earliest times, at first curious and speculative, but afterwards strong and powerful minds have, without interruption almost, bent all their energies upon the solution of these grand problems that we are able to comprehend how it is that light now breaks in upon us from what was the very confines of the universe, dimly revealing those mysterious forces which lie yet half concealed in the unfathomable depths of space. To trace the efforts of the human mind in the very commencement of this long and arduous struggle, and to develop the means whereby the foundation stones of that rock-built temple of the science of astronomy have been laid, this is the object propounded here for accomplishment, and this the topic to which I would invite your attention. It is true that, in many instances, history yields no light, and tradition even fails; but such is the beautiful order in the chain of discovery, that those links which are known reveal with certainty those which are buried in the voiceless past. Were it possible to read the records of the origin and early days of astronomy, graven on some tablet of stone, we now know — thanks to the triumphs of modern prehistoric research — what its hieroglyphics would reveal, with a certainty scarcely less than that which would be given by an actual discovery, such as we have imagined.

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[1] 'The civilised man has built a coach, but has lost the use of his legs. He is supported on crutches, but lacks so much support of muscle. He has a fine Geneva watch, but he fails of the skill to tell the hour by the sun. A Greenwich nautical almanac he has, and so being sure of the information when he wants it, the man in the street does not know a star in the sky. The solstice he does not observe; the equinox he knows as little; and the whole bright calendar of the year is without a dial in his mind.'—Emerson's 'Self-Reliance.

§ 18. Of all the heavenly bodies which first engaged man's attention, the first was, we know, the MOON.

'The cold, chaste Moon, the Queen of Heaven's bright
isles;
Who makes all beautiful on which she smiles,
That wandering shrine of soft yet icy flame,
Which ever is transformed, yet still the same,
And warms not but illumines.'[1]

For those nights on which there was no moon would be distinguished by the shepherds[2] of antiquity in a marked way from those in which the moon was full or nearly so; for all his cares were doubled when she was not shining, all lightened when she was nearly full. Homer, after describing the beauty of a moonlight night, closes his description with the words, 'The shepherd gladdens in his heart.' Her extraordinary phases would ere long have riveted his attention. Whence came they? Her companion orb, the sun, was ever round and brilliant; the stars shone with a steady light and undimmed splendour, whilst the moon was ever waning and waxing—sometimes a thin silver crescent in the western sky, or full-orbed, moving in majesty amongst the stars. The first thing which he would observe about these phases would evidently be their periodicity, that they took place regularly in a period of about 30 days. And the first use which man in ancient times made of the moon was undoubtedly that of a time measurer; indeed, we might go further, and say that it was for this purpose that they first observed the moon. Her changes and motions would evidently be the *first* methods used for measuring time; and the word meaning 'moon' in some ancient languages confirms this statement; and the moon measures off time in such an obvious and striking manner, and, to ordinary observation, with perfect uniformity, far more so than the alternation of night and day. The circling motion of the moon being noted, men would naturally soon think of sub-dividing her circuit. And thus the lunar month came in course of time to be sub-divided into two halves, each about a fortnight in length; and, to the shepherds of old time, this bright half and dark half of the month would be of the utmost importance, as we have already pointed out. The division of the month was not, however, as might at first sight appear, marked off by the moon (1) coming to full, and (2) disappearing; but at her quarters, when she was half-full increasing, and half-full diminishing. The circumstances which lead us to form this conclusion are—(1) the naturalness of dividing the month into a bright and dark half; (2) her quarters are much more easily determined than either her 'full' or 'new' phase; for she looks 'full' a day or two before she really is so, and her 'new' phase (or absolute disappearance, in reality) was not determinable in those days with anything like precision. And corroborative evidence has been found in the ancient Vedic literature of the Hindoos—the month being divided into two, according to the moon, the *clear* half and the obscure half; and in some Assyrian tablets lately deciphered by Mr G. Smith (copies of some very, *very* ancient

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[1] Shelley.

[2] The *first* astronomers were undoubtedly shepherds and herdsmen; for the life of the shepherd, unlike that of his predecessor the huntsman, was one requiring nightly vigil. It is no mere fancy or idle tradition that assigns to the shepherd and herdsman the *rôle* of the earliest astronomers—they who

'Watched from the centres of their sleeping flocks
Those radiant Mercuries that seemed to move,
Carrying through aether in perpetual round,
Decrees and resolutions of the gods.'—WORDSWORTH.

And, moreover, we find amongst the most ancient objects pictured by man's fancy in the heavens, those animals in which the shepherd was most interested. For we find there the Ram and the Bull, the Waggoner bearing on his shoulders the two kids, and the Herdsman with uplifted arms (well seen in the heavens even in our day, though no longer existing in star maps), driving from his flocks the Bear and Lion, the creatures most dreaded by the shepherds of old time.

Chaldean ones, by the way), the following occurs:—'At the beginning of the month, at the rising of the night, his horns are breaking through, and shine on the heaven; on the ninth day to a circle he begins to swell.' The month, therefore, amongst the earliest astronomers, began at that quarter of the moon when she was half-full, increasing or changing from the horned to gibbous phase. After the foundation of this first 'lunar' month and its two halves, would naturally arise, in course of time, the division of each of these two halves into two equal parts; after some months of observation, men would perceive that about 14 or 15 days separated the times of half-full, and that 'full' or 'new' came about 7 days after the times of half-moon. Thus arose, in course of time, *the week of seven days*—the origin of our own, and one of the earliest divisions of time used by man. It would probably be, however, some time before men began to think of connecting months and days together. The occasion arose, perhaps, in the following way:—'The most likely, perhaps,' says R. A. Proctor, 'would be the necessity of apportioning work out to those employed as herdsmen or in tilling the soil.' The hiring of pastoral and agricultural labour was evidently made, in the first instance, by the month. The 29th chapter of Genesis, which contains the earliest record of hiring, corroborates this. But herdsmen and labourers, though the phases of the moon would show them in a rough kind of way how their term of labour was passing, would ere long require a more definite and sometimes shorter period than the phases of the moon afforded, and thus at length a month of days and its subdivision must have come into use.

On watching the moon, these early astronomers must, ere long, have observed her backward motion amongst the stars, and by counting the days which elapsed while the moon was passing round the heavens from a certain bright star, or group of stars, to this same star or group again, it was discovered that the time of this revolution was about 28 days; more careful observations afterwards fixing this period as 27⅓ days, or about the same time as that taken by the moon to pass through her phases; at first they were, no doubt, thought to be the same. The discrepancy between the moon's circuit and four weeks would remain, in all probability, long undetected; and so long as this was the case, the moon's pathway amongst the stars would be divided into twenty-eight daily portions; and we accordingly find in the early astronomy of nearly all nations a lunar zodiac divided into twenty-eight lunar constellations — this division having been found, for instance, adopted amongst the Chinese, Egyptians, Arabian and Persian astronomers. These divisions were not, of course, in those early times precisely defined, but, as we might expect to find from the comparative roughness of a system of astronomy in which they should appear at all, were very irregular divisions, straggling far on either side of the moon's pathway amongst the stars. We perceive in this, however, the origin of the mapping out of the heavens into constellations—one of the most important gifts of semi-primitive astronomy to man. This backward motion of the moon amongst the stars must have sorely perplexed the earliest astronomers; analogy would lead them to the conclusion that as the stars apparently revolved from east to west, the moon, in all probability, participated in that movement, and their solution of the mystery would, doubtless, be by giving to the moon a slower motion from east to west than the general motion of the heavens. She would then appear to lag behind the stars, and thus occasion in her the observed backward motion. Later on it will be seen how this error was detected.

§ 19. But though the moon, in the infancy of the science, engaged nearly all the attention of the earliest astronomers, and though those stars along the moon's track were, in all probability, the first observed, certain bright and conspicuous groups must ere long have engaged his attention; and these were watched to see if they, like the moon, were subject to change. What was the result of their observations? In watching the heavens (in the north, suppose) through an entire night, it would be seen that they all appeared to describe circles, which grew smaller and smaller as the stars approached nearer and nearer to the central point of revolution, until finally, in the neighbourhood of one bright star, a position was found which was for ever fixed, immovable, whilst all else revolved. This discovery of the pole of the heavens was one of the most precious gifts of pre-historic astronomy to man, for its use in guiding him in his wanderings over the earth must, ere long, have been recognised. As soon as the early astronomers began to pay any attention to the stars in general, there is one group which would at once arrest their attention—*the Pleiades;* and in course of time the regular return of this group, at times corresponding to particular parts of the year of seasons, would be observed by the shepherds and tillers of the soil; and it was probably this group of stars which first led to a precise determination of the year, the first rough determination being made by the regular variation of the sun's altitude, etc., as the year progresses. This constellation of the Pleiades constantly occurs on the Babylonian monuments and cylinders, a proof that it was very early in the infancy of

Note.—The ancient Egyptians early observed that the rising of the Nile coincided with the heliacal rising of Sirius; its coming to the desired position was, therefore, eagerly expected, and it was ere long observed that this took place at periods of 360 days. This was, in all probability, the first determination of the year amongst this ancient people.

astronomy carefully observed. The suitability of the stars for many purposes (except in the case of the ancient Egyptians, perhaps) is not a circumstance which obtrudes itself on the attention, and many years would doubtless pass before men would notice that the same stars were seen at corresponding hours of the night at the same season of the year; for this is less striking than the regular variation of the sun's altitude, etc., as the year progresses.

Watching the constellations near the moon's track slowly disappear in the effulgent rays of the sun, the astronomer of old observed that, when they were next seen, it was in the east, at early dawn, emerging, apparently, from the beams of the sun, having actually passed by the sun in the interim. Further observation showed him that the entire starry heavens were slowly moving forwards to meet the sun, or else the sun itself was moving backwards amongst the stars. The sun, then, as well as the moon, was moving amongst the fixed stars, not *apparently*, but *absolutely*. The explanation of the moon's motion previously believed in could no longer, therefore, be accepted, for the starry heavens could not at the same time so move as to pass by the moon in one month, and the sun in a period twelve times as great. From the facts already gained, some most important conclusions followed. The starry heavens passed around and beneath the earth; both the sun and moon were wandering amongst the fixed stars, in the same direction, but with different velocities; the stars were invisible in the daytime, not because they did not shine, but because their rays were lost in the superior brilliancy of the sun. The heavens were spherical, and encompassed, like a shell, the entire earth, which occupied the centre of this starry sphere. How many centuries it took to acquire this knowledge, trivial though it may seem, can never, of course, be known, but it must have been, in all probability, very many, for the first steps in any knowledge are, we know, the most difficult of acquisition, and require the longest period for their comprehension. How slow is a child in acquiring its earliest knowledge? and the history of a child is the history of the early ages in miniature.

So far, the only moving bodies observed in the heavens were the sun and moon. Whilst watching the sun as he heaved upward to meet the coming constellations, however, some enthusiastic and ardent observer at length marked in the early dawn a certain bright star closely attendant on the sun. Further observation showed that this star, unlike the rest, was not fixed, but was either gradually approaching to or receding from the sun. *The first Planet was discovered.* The discovery of one planet would, ere long, lead the way to the discovery of the others. The precise order in which they were discovered cannot, of course, now be determined with certitude. Mercury was, perhaps, the first one observed as a strangely moving body, never seen except near the sun, and passing rapidly from one side to the other; for, though Mercury is never beheld by us as a conspicuous orb, in a clearer and less humid sky Mercury shines out with resplendent lustre, well justifying the name given him by the ancient astronomers—'the sparkling one.' Venus, on account of her lustre and her alternating appearance on either side of the sun, was probably the next observed, if she was not the first discovered. Jupiter and Mars would be the next discovered, being distinguished from the fixed stars by their movements; and these, as soon as they were discovered, would be seen to be travelling in the zodiacal track, though it was probably some time ere Mercury and Venus were recognised as having the zodiac for their pathway. Saturn, in course of time, would then be recognised as a planet, either by his movement or by his peculiar light, which distinguishes him in a marked degree from the other planets. In time their curious and perplexing motions—

'Now high, now low, then hid,
Progressive, retrograde and standing still,'

would be observed, and their periods of revolution approximately determined from the 225 days of Venus to the 10,759 of Saturn. We then have, if they had not been previously discovered, the determination of the summer and winter solstices, and the vernal and autumnal equinoxes, the obliquity of the ecliptic, etc., and it is in connection with these discoveries that the *first instrument* ever used by man in connection with that sublime subject of astronomy was probably employed. It was a most simple instrument, truly—one can hardly conceive of a more simple one — merely a straight pole placed vertically upright upon a smooth and levelled piece of ground; and yet one which, by carefully observing the noon shadows of the pole cast by the sun, enabled the early astronomers to determine, with some degree of accuracy, the four cardinal points, north, east, south and west, the epochs of the solstices and equinoxes, the obliquity of the ecliptic, the latitude of a place, etc. In counting the days from summer to winter solstices, and from winter round to the summer solstices again, these early astronomers found the intervals unequal. And this was confirmed by the fact that the shortest space from equinox to solstice, dividing the sun's annual route into four equal portions, were passed in unequal times. Having started with the idea that the sun moved with uniform velocity in a circular orbit, rendered this problem, of course, for the time being insolvable, and it was handed down to succeeding generations for solution.[1] Meanwhile, other problems were pressing upon these early astronomers for solution. The phases of the moon, the very first point of investigation, were as yet unaccounted for, and those most awful and terrific phenomenas, lunar and solar eclipses, were as yet only a source of terror and dismay. Into these laborious, patient and long-continued watchings and observations of the semi-primitive observer, which led them first to perceive that a solar eclipse was caused *by the interposition of the* DARK *body of the moon* (and, therefore, that moonlight was but *reflected* sunlight), and a lunar eclipse by the interposition of the dark body of the earth: or which led them, by the careful recordation of all eclipses for many, many centuries, in after years to perceive that eclipses occurred approximately in a certain cycle of time, and that they might, therefore, be expected, and their coming *foretold*, space forbids us to enter here. This discovery of the famous so-called *Saros* of the Chaldeans justly ranks amongst the most wonderful and important of antiquity. It was the first triumph of Science and Knowledge over Superstition and Ignorance, the first of those immortal battles between Error and Truth, which will be continued to the end of time, but in, which—'The *Truth* comes ever uppermost.'

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[1] The Chaldeans appear, however, to have solved the problem, *vide* § 6.

Such is a brief sketch of a few of the features of the early evolution of astronomy, which so perfectly illustrates 'the gradual growth and development of the powers of the human genius' . . . [for] 'there never has been a time when astronomy did not present problems, not only equal to all that man could do, but passing beyond the limits of his greatest intellectual vigour. Hence, in all ages and countries, the absolute strength of the human genius may be measured by its reach to unfold the mystery of the stars.'

How important is it, therefore, that we should all of us be, more or less, acquainted with a subject which will tell us so much about the development of the mind of man.

THE human brain is an organised register of infinitely numerous experiences received during the evolution of life, or, rather, during the evolution of that series of organisms through which the human organism has been reached. The effects of the most uniform and frequent of these experiences have been successively bequeathed, principal and interest, and have slowly mounted to that high intelligence which lies latent in the brain of the infant—which the infant in after life exercises, and perhaps strengthens or further complicates—and which, with minute additions, it bequeathes to future generations. And thus it happens that the European inherits from twenty to thirty cubic inches more brain than the Papuan. Thus it happens that faculties, as of music, which scarcely exist in some inferior races, become congenital in superior ones. Thus it happens that, out of savages unable to count up to the number of their fingers, and speaking a language containing only nouns and verbs, arise, at length, our Newtons and our Shakespeares.—HERBERT SPENCER—*Principles of Psychology*.

CHAPTER II.

MATHEMATICS.

Περι Αἴγυπτον αἱ μαθηματικαι πρωτον τεχναι συνεστησαν.—
ARISTOTLE—*Metaph.* i. 1.

§ 1. WE pass on in this chapter to the science of mathematics as known to the ancient Egyptians. The subject is one full of the deepest interest, for if it be true, as the classical writers of antiquity tell us, that it was at the priestly schools of ancient Egypt that the Greeks were first initiated into the mysteries of this, the most wonderful in many respects of all the sciences, and the model upon which all other sciences are constructed, it must be well worth inquiry what progress the ancient Egyptians made in this science, and the means by which such progress was effected. The general reader will no doubt find the greater part of this chapter somewhat 'dull' reading, nevertheless, we ask his perusal of it, both because an examination of this science, as studied amongst this ancient people, reveals to us so many curious revelations, which it is, by the way, the especial duty of the student of history to answer; and secondly, because the mathematics dealt with in these pages are only such as are more or less known to every Englishman of the present day, which should serve, at any rate, to make the subject both intelligible and interesting; and lastly, he should remember that *his* mathematics, *i.e.*, the mathematics taught in our schools at this present day, are founded upon, and are, in fact, the very outcome of the labours of this (and other) ancient people. Of the utility of these discoveries he is well acquainted; for though he *may* be successful in his vocation without any knowledge of Latin or Greek, French or German, or without a greater knowledge of geography than the position of the nearest post-office, he most certainly cannot be so without a knowledge of the rules of more or less, of addition, subtraction, of multiplication and division, discovered and laid down by these very same people of antiquity. Such being the case, an account of how these same rules were first discovered and exemplified cannot fail, I think, to be a subject of more or less interest to every one, however little he may care about the study of history in general, or that of science or mathematics in particular.

§ 2. The science of mathematics was a favourite study amongst the ancient Egyptians from a period of the remotest antiquity. Professor Eisenlohr has discovered that this science was studied at the court of the Hyksos princes. This discovery has been made by the decipherment of a papyrus included in the Rhind collection of the British Museum; the facts which it contains being of the greatest interest and importance, both as showing approximately at what period certain mathematical results were known to mankind, and furnishing, as they do, the only compact mass of evidence concerning the difficulties which beset ancient mathematicians, and the manner in which they were overcome; for this papyrus, with the exception of an older leather-roll on a mathematical subject, too stiff, apparently, to be opened and deciphered, is the only treatise on mathematics that the ancient Egyptians have left during their civilisation of probably more than 5000 years.

§ 3. The book, or papyrus, was written, or more correctly, perhaps, compiled, in the same manner that Euclid compiled his famous 'Elements of Geometry,' though not with his skill or care, by one Ahmes (Aahmesu—moon-born), in the reign of Ra-ā-us (Apepa or Apophis of the Hyksos, sixteenth or seventeenth dynasty), some time before 1700 B.C., but it was founded on and follows, *not always correctly*, an older work, written most probably about 3400 B.C., *i.e.*, at a period when the Chaldeans were making frequent incursions into the land of Egypt—a fact worthy of careful notice. It is entitled, 'Directions for obtaining a knowledge of all dark things;' but it contains, in fact, hardly any general rules of procedure, but chiefly mere statements of results, intended, possibly, to be explained by a teacher to his pupils. This fact has led some to suppose that it was a papyrus serving merely for instruction in elementary schools, and by no means exposing all the mathematical knowledge that the ancient Egyptians had acquired up to that period. The fact, however, of its arithmetical portions dealing chiefly with *fractions* serves to show, however, I think, that this is not the case, but that it was compiled for the *élite* of the ancient Egyptian mathematicians of his time, for fractions were, we know, the greatest and most serious stumbling-block to ancient calculators; and, moreover, though there is truly no *direct* evidence that this work represents the highest attainments of the ancient Egyptians in the science of mathematics, yet two facts raise a presumption that Ahmes' book represents the greatest achievements of the ancient Egyptians in the science of *arithmetic*, at any rate. First, no improvement was made by them in Egyptian arithmetical symbolism; and secondly, the Greeks did not derive from Egypt, as far as we know, any more arithmetical learning than is contained in the work of Ahmes.

§ 4.[1] The work commences with a series of exercises in reducing fractions, with 2 for numerator, to submultiples. 'Divide 2 by

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[1] The reader will find a fuller account of the arithmetical portions of this work given in J. Gow's 'Short History of Greek Mathematics,' pp. 16-20; and a still fuller account in Prof. Eisenlohr's '*Ein Mathematisches Hanbuck der alten Egypter*,' Leipzig, 1877.

5, or express 2 divided by 7,' etc., is his mode of stating the proposition, and he gives immediately afterwards a table of answers for all fractions, such as $\frac{2}{3}$, $\frac{2}{5}$, $\frac{2}{7}$, $\frac{2}{9}$; or in other words, of the form $\frac{2}{2n+1}$ up to $\frac{2}{99}$. Why he confines himself to fractions the numerator of which is 2, Ahmes does not say; nor does he tell us how he obtains, in each case, the series of multiples which he selects. It is most probable that fractions with a numerator higher than 2 were sub-divided. And with regard to the second question, 'How he obtains, in each case, the series of submultiples which he selects?' there is much evidence (of too technical a nature to be considered here) to show that the fractions of the table were determined empirically, probably by different persons and at different times. An absolute neglect of the most simple and obvious analogies is observable throughout the entire table.

§ 5. Directly after this table, Ahmes gives six calculations, most unfortunately mutilated, showing how to divide 1, 3, 6, 7, 8 and 9 loaves respectively among 10 persons. Then follow 17 examples of *seqem* calculations, *i.e.*, of raising fractions by addition or multiplication to other fractions, or to whole numbers. Ahmes does not in any case multiply *directly* with a high number, but proceeds by many easy stages. In order, for example, to multiply by 13, he multiplies first by 2, then (doubling) by 4, then (doubling) by 8, and adds the necessary products. This fact is an interesting one, showing as it does the care and caution which a man has to take in dealing with a new science, or with one taxing all the powers of his intellect. From examples given here and elsewhere in the papyrus or book, it is plain that Ahmes was not acquainted with direct division.[1] If it was required to raise *a* by direct multiplication to *b*, his plan was to multiply *a* until he found a product, which was either *b* or nearly so—the difference, if there was any, being treated separately.

§ 6. Timid and tentative though these methods appear to us, what centuries of progress, what generations of patient and thoughtful men, and what years of patient calculating and empirical table compiling must separate *their* culture, their *science* (now beginning to be worthy of that name) of arithmetic from that of primitive or semi-primitive man, unable to count beyond 5, and not possessing distinct names for things beyond 3! The evolution of arithmetic is a most interesting study, and it is a problem to which modern science has given a most satisfactory and complete answer. Modern science has successfully spanned that immense interval that separates the period in which Ahmes compiled his work from that in which man *first* made the transition from number in the concrete to number in the abstract—from number, as having reference to some particular kind of unit—as five horses or five persons—to the idea of number as having reference to no particular kind of unit. The science of arithmetic owes its origin to the rawest of materials, the most simple of ideas, from the primary idea of more or less, counting and measuring — reference being at first naturally made to some part of the human body, as always being present for identification—as is shown by our words cubit (*cubitus*, of similar signification), yard (*geard*, gynd, the girdle), *ulma*, the elbow, *i.e.*, the fore-arm; digit (*digitus*, finger, *i.e.*, a finger's breadth), foot, etc. In the earliest transactions of semi-primitive races, articles of barter were most probably transferred by tale, and *number* constituted the only measure of quantity.[1]

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[1] Nor are any examples of simple division, nor any rules for division, found in Greek arithmetical literature. A timid and very lengthy 'compound' division is first found in Theon's (380 A.D.) 'Commentary on Ptolemy's *Almagest*.' It was not until the sixteenth century that Double Rule of Three and Decimals were introduced.

Semi-primitive people, then, having learnt to generalise, began in course of time to learn to count. They commenced counting with groups of two or three, but the most enlightened amongst them ere long arrived at counting five. When they reached this limit, their counting, or rather their actions, became pantomimic; for they at once began to use their fingers, and then their fingers and toes, as a means and basis of calculation, and are therefore henceforth committed to a quinary, or denary, or vigesimal scale. At first, each number would evidently have a perfectly distinct and independent name; the gestures used in finger-counting suggesting names for the first five and the higher units. And with such names, and with the use of the fingers and toes, it was possible to attain fair dexterity in the art of calculation with whole numbers, the numbers from 10 to 100, no doubt, at first requiring, as in South Africa at the present day, two, and those from 100 to 1000 three calculators. The assistance of coadjutors could be and *was* in course of time dispensed with; in mere counting, as soon as the memory began to be trained to remember, without embarrassment, the multiples of ten, or the habit was adopted of making a mark or setting aside a symbol at the completion of each group of 1000. Addition can be performed with the fingers, and was so performed in early times; but in the case of high numbers, the process involved a very severe tax on the memory. In the case of subtraction, this tax was increased, because here, to take the most favourable condition, the numbers have to be remembered backwards. To assist him in these operations, therefore, semi-primitive man called in the assistance of small pieces of stick or other symbols, the most common, perhaps, being pebbles or stones (ψηφοι, *calculi*), the origin of the word itself showing that it was so used. And it must be remembered that the multiplication table is merely a summarised statement of additions, and a division table a summarised statement of subtractions. Continual practice, leading to well-remembered inductions, would, in course of time, give them considerable facility in the four rules of arithmetic. Only division, when it came to be conducted with care, introduced a new difficulty. The divisor was not always a whole factor of the dividend, and there was a remainder. What was to be done with this? This led to the consideration of fractions; fractions with low denominators being naturally long familiar to semi-primitive man before those with high denominators were used at all, this leading him to express, as we now know he did express, the latter in terms of the former. The way in which the question of fractions first arose is full of interest, and as its consideration presents no difficulty, I purpose devoting a few words to the subject. The question first arose, no doubt, in connection with concrete units; in a case, for instance, let us suppose, where 23 apples were left to be divided amongst 24 men. Here, obviously, each man will obtain a fraction of an apple; but there are, however, two ways of ascertaining this fraction. One is, divide each apple into 24 equal parts, and give 23 such parts to each man. The other is to sub-divide 23 into groups, say 12, 8 and 3, and thus to give to each man first $\frac{1}{2}$, then $\frac{1}{3}$d, then $\frac{1}{8}$th of an apple. Now, this latter method of treating a remainder (by taking parts of it at a time), is clearly analogous to the manner in which the whole dividend has previously been treated, and therefore it commended itself to ancient calculators on this account. But it has also an especial advantage in this, that the fractions which it produces are more easily represented by means of primitive symbols. For it would puzzle any man to represent directly a fraction such as $\frac{23}{24}$ by means of his fingers, pieces of stick or pebbles, but it would not be so difficult to represent $\frac{1}{2}+\frac{1}{3}+\frac{1}{4}$. And another advantage of the same kind could attend the practice of dividing the unit always into the same fractions (say 10ths or 12ths), and expressing every other fraction as nearly as possible in terms of these. As by means of the former plan the numerator of a fraction might be taken for granted, so, with the latter, the denominator might be similarly treated, and the symbols and calculations relating to fractions made nearly the same as those for whole numbers. That this was so we know from the fact that the ancients *did* always avoid the necessity of handling the numerators and denominators of fractions together; the Babylonians and Chaldeans by using only the sexagesimal fractions of a degree, and in later times the Romans used only the duodecimal fractions of the *as;* the denominators being in these cases merely implied. And on the other hand, a series of 'submultiples' or fractions, with unity for a numeration, thus avoiding the treatment of the numerator.[1]

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[1] In the philosophy of Pythagoras, number, we know, was quantity, and quantity was form, and form was quality. He considered number as the basis of creation; and he looked to arithmetic for his definition of all abstract terms and his explanation of all natural laws. Number, in fact, seems with him to have been 'everything in turns.' Having learnt in Egypt that number was essential to the exact description of forms and the relations of forms, he concluded that number was the cause of form, *ergo*, of every other quality.

The *antiquity* of the origin of arithmetic cannot be, perhaps, better illustrated than by the following remarks of Professor Max Muller:—'In every language of the Aryan race all the numerals are the same. But think what this means. The decimal system must have been elaborated and accepted by the ancestors of our race before they separated, and every number, from one to one hundred, must have received its name; and all these names must have been sanctioned, not by agreement, but by use, or, if you like, by the survival of the fittest. How old these numerals are is best shown by the fact that they cannot be derived from any of the roots known to us, so that we cannot tell why six was ever called six, or seven seven. And yet in Sanskrit, Zend, Armenian, Greek, Latin, Slavonic, Celtic and English, we find exactly the same series of numerals.'

So far we have been dealing with the evolution of concrete numbers, the arithmetic of the man of business, the merchant, etc. But, ere long, another arithmetic arose—the *science* of arithmetic in its proper sense. For as civilisation advanced, and man's social (or warlike) needs multiplied, and his intelligence increased, there arose the necessity of inventing *names* for higher numbers; then the difficulty of inventing names for every number, even to a limited extent, and of remembering them when invented, would lead to a classification and arrangement of them. Then arose the difficulty of performing calculations by mere names, a process which must be performed by some mechanical means. The necessity of inventing *signs* or characters to represent numbers to facilitate the progress of calculation would become more and more obvious as society advanced in civilisation; and thence arose the invention of an arithmetical notation — an invention coeval with the very earliest use of writing, whether hieroglyphic or otherwise, and which must have been made about the same time when it was felt that a mound, a pile of stones, or a huge misshapen pillar was insufficient as a record of passing or past events. This period was, without doubt, the most noteworthy and important in the earliest history of mankind, for then it would be that man first made the transition from number in the concrete to number in the abstract—from number as having reference to some particular kind of unit, as 5 horses or 5 persons, to number as having reference to no particular kind of unit, merely 5. And from the origin of this 'abstract' arithmetic dates also, one might say, the origin of civilisation. For then commenced the beginning of *all* abstract thought; for number is a principle common to nearly every branch of learning, giving distinctions to expression and clearness of thought to ideas then floating in untutored minds, and, by so doing, suggesting to them new conceptions. 'In "the one," "the all," "the many in one," terms of purely arithmetical origin, it gave the earliest utterances to semi-primitive man's first crude ideas about God and the world. It supplied, in fact, in many instances, a vocabulary of speech for the moral notions of mankind, and quickened them by giving to them the power of expression.'[1]

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[1] Even the Greeks, though they could *state* fractions as easily as whole numbers, still calculation of any kind was still so difficult to them that they preferred to get rid of numerators, and to reduce denominators to a series of numbers, some of which were so low that they could be handled mechanically, and the rest so high that they could generally be discarded without materially affecting the result.

The most natural method of first denoting numbers by signs would be by means of upright strokes: thus | signifying 'unity,' || signifying 'two,' ||| signifying 'three,' and so on. And we find that this was the case, for the ancient Egyptians, from the very earliest times, used a like notation; the original or primitive cuneiform writing of the Turanian Chaldeans was evidently formed by combinations of the straight line; the wedge, or sometimes hammer-headed appearance that their writing usually represents evidently being a later production; the Assyrian letters and numerals were both expressed by various combinations of the wedge. The Roman notation, too, is easily derivable from combinations of straight lines. From these, the very earliest of man's endeavours to represent numbers by signs arose, we know, in the course of time very many ingenious systems to overcome that great difficulty to the calculators of antiquity, viz., fractions, from which arose that grand but so extremely simple arithmetical notation of modern times, invented, as far as we know at present, by some unknown Hindoo of uncertain date. Such are the vagaries of fortune; here is an instance of a man who conferred an incalculable benefit an all coming generations, and yet, owing to a caprice of fortune, not only is his name unknown, but even the epoch and country wherein he dwelt are but matters of pure conjecture.

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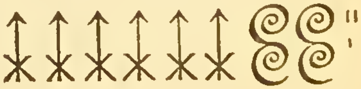
[1] Professor Spottiswoode.

§ 7. The foregoing paragraph is full, it is true, of some very dry details, but I have inserted it because its perusal must, I think, convince the reader that the period when the original work from which Ahmes copied was written (about 3000 B.C.) is a period when man was by no means making his first attempts at calculation. Many, many centuries of culture must separate the mathematician of that epoch from the mathematician of the finger and toe counting epoch,' when calculations in hundreds required two, and calculations in thousands three calculators. Before passing on to consider the remaining or *geometrical* portions of Ahmes' work, I may as well mention that the ancient Egyptians possessed a numerical notation similar to that of the Phœnicians, Etruscans and Romans, whereby distinct signs being attached to the unit, to 10, to 100, to 1000, 10,000, etc., other numbers were expressed by a repetition of these characters. Thus, as MMMMMMCCCXIII represent 6313 in Roman figures,  represents the same in ancient Egyptian characters; and similarly with all other numbers, except that the ancient Egyptians did not possess special signs for 5, 50, or 500, like the Roman V, L, D. Numbers were dealt with as far as millions,[1] and would no doubt been carried further had it been necessary for practical purposes.

§ 8. After this preliminary practice with fractions in arithmetic, Ahmes proceeds to the solution of *simple equations with one unknown.* The unknown quantity is called *hau*, or 'heap.' In these examples, a pair of legs walking, so to speak, with or against the stream of writing, were used as mathematical symbols of addition and subtraction. Three horizontal arrows indicated difference,' and a sign $\overline{<}$ meant 'equals.' Eleven such equations are given, of which we subjoin one. 'Heap, its 7th, its whole, it makes 19' (or that is, in the language of modern algebra,—$\frac{x}{7}+x=19$). In this particular case, Ahmes goes on in effect to state that $\frac{8x}{7}=19$. He then divides 19 by 8, and multiplies the quotient $(2\frac{1}{4}+\frac{1}{8})$ by 7, and so finds the desired, number, $16\frac{1}{2}+\frac{1}{8}$, or $16\frac{5}{8}$. This discovery of the fact that the solution of simple equations was known to mankind probably more than 5000 years ago, came as a wonderful revelation to the modern scholar, showing with such force as it did the antiquity—the vast and almost incomprehensible antiquity—that must be in consequence assigned to many discoveries which we had been accustomed to look upon as being almost of yesterday. These equations are followed by a table of Egyptian dry measures, and then are added two example of *Tunnu*, or difference-calculation, *i.e.*, of divisions, according to different rates of profit. The examples are,—'Divide 100 loaves so that 50 go to 6, and 50 to 4 persons;' and 'Divide 100 loaves among 5 persons so that the first 3 get 7 times as much as the other 2.' What is the difference? (*tunnu*). After this, Ahmes passes on to geometry (which we will consider further on), recurring, however, at the end of the book to algebraical problems, and gives about

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[1] The number of objects mentioned in the 'Great Harris Papyrus' exceeds a million. 'Records of the Past,' vol. vi. and vol. ix. pp. 43-5.

20 more examples of the same kind. Most of these are more or less simple, but in at least three Cantor (*Vorlesungen*) sees evidence that Ahmes was acquainted with the theory of *arithmetical and geometrical series*. The evidence, however, for Ahmes' knowledge of *geometrical* series is confined to the fact that in one example (No. 79) he states such a series and calls it a 'ladder' (*Sutek*).[1] In the solution of some of these examples, Cantor has pointed out (*Vorl.* p. 36) that there occurs the first known instance of a '*falschar ansatz*,' or *falsa positio*, or 'tentative assumption,' so much used by later mathematicians.

§ 9. The expectation naturally arising in the mind of the reader on a perusal of this is, no doubt, that a nation which possessed, at such an early period in its history, so much arithmetical knowledge, and amongst whom dwelt men who had already acquired so much proficiency in the science, would, in the course of another thousand years or two, make much further progress, or would, at least, discover and begin to remove the obstacles which rendered such a progress impossible. He is, however, doomed to disappointment; not only, as far as we know, did the Egyptians of a later day add nothing whatever to the learning of 'Ahmes'' day, but in some respects (in the subject of geometry, for instance) they actually retrograded, and have left us instances—as we shall see — of geometry of which even Ahmes himself would have been ashamed. The two facts which allow us to state that Ahmes' book represents the highest attainments of the ancient Egyptians in the sciences of arithmetic and algebra, are—First, no improvement was made in ancient Egyptian arithmetical symbolism; and secondly, the Greeks did not derive directly from the ancient Egyptians any more arithmetical learning than is contained in Ahmes' work. Even the ancients themselves, who were indebted, in some part at any rate, to the ancient Egyptians for the rudiments of many sciences, observed with surprise that they made no further advances in them. Leaving this most interesting question for the present, as to *why* the ancient Egyptians made no such progress, let us pass on to the remaining portions of Ahmes' book, viz., those treating of *Geometry* and *Trigonometry.*

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[1] For a fuller account of this portion of Ahmes' papyrus, see J. Gow's 'Short Hist. of Greek Maths.,' p. 19

§ 10. This same work of Ahmes' contains, besides the arithmetical and algebraical matter already cited, a great number of geometrical examples. It is curious and worthy of notice that all the geometrical matter occurs in the *middle* of the arithmetical, and that (contrary to what we should expect) the calculation of solid contents precedes the calculation of areas. From this circumstance, it has been inferred that the geometrical propositions known to Ahmes were empirically obtained, and that he was really only interested in the arithmetical problems which they suggested. Immediately after the examples of *Tunnu*, or difference calculated mentioned above, Ahmes proceeds to calculate the contents of barns and other similar receptacles, of which he does not, unfortunately, give the shape, so that the necessary key to their interpretation is wanting.[1] With regard to the examples in plane geometry (Nos. 49-55), the figures given by Ahmes (which are, by the way, very badly drawn) are sufficient, save in a few cases (Nos. 53, 54. Eisenlohr, pp. 118-133), where *solutions and figures are given which have no connection whatever with the problems to which they are appended* (which fact I wish the reader particularly to note). The rectilineal figures, or the figures bounded by straight lines, of which Ahmes calculates the areas are the *square*, *oblong*, *isosceles triangle*, *i.e.*, a triangle having two equal sides, and the *isosceles parallel trapezium* (*see* figure A). He calculates the areas of the first two correctly, the last two *in*correctly. Thus, in Ex. 51, he draws an isosceles triangle, of which the sides measure 10 *ruths*, the base 4 *ruths*. He finds the area at 20 *ruths* instead of 19·6. Similarly, in No. 52, the area of an isosceles parallel trapezium he finds as 100 square *ruths*, instead of 99·875. The errors are

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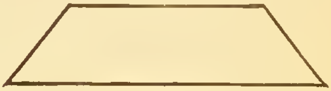
[1] The contents of all the barns are found by multiplying 2 of the 3 linear measurements together, and then multiplying the product by *one and a half* of the 3d. But it does

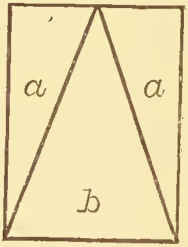
FIG. A.



not appear whether the first product is the area of the top, side or bottom, or of what line the third given number is a measure.

small, but suggestive. One can hardly suppose that Ahmes was unacquainted with the fact that 'an isosceles triangle' was, in area, one-half that of a rectangle or oblong on the same base, and of the same height or altitude. Now, the area of any square, rectangle or oblong, as every schoolboy knows, is found by multiplying two of its adjoining sides together, or, in other words, multiplying its length by its breadth. Ahmes himself knew this, Exs. 49 and 50 prove it. Now, the triangle being one-half this rectangle in area, it at once becomes apparent that, either the base of the triangle (which is the breadth of the rectangle) must be multiplied by one-half the height of the triangle (*i.e.*, the length of the rectangle), or one-half the base by the height of the triangle. What Ahmes appears to have done is this. If, in figure B, a and a be the two equal sides in an isosceles triangle, and b be the base, then the true area is $\frac{b}{2}\sqrt{a^2 - \frac{b^2}{4}}$. Now Ahmes makes the area $\frac{ab}{2}$, *i.e.*, 20 *ruths*,

FIG. B.



neglecting the difficult square root. Similar remarks apply to his method of finding the area of the isosceles-parallel-trapezium. In Example 50, we have the first record of man's earliest attempt to solve that famous problem of the 'Quadrature of the Circle;' for in this example Ahmes calculates the area of a circle by deducting from the diameter $\frac{1}{9}$th of its length, and squaring the remainder. In this example, what is known 'as the ratio of the circumference to the diameter,' or $\underline{\Pi}$, is taken as being equal to $\left(\frac{16}{9}\right)^2$ or 3·1604,[1] a fair approximation only, and one easily obtainable by mechanical means. Such is the contents of the geometrical positions of Ahmes' work. And crude and imperfect though it is, what ages of culture and civilisation separates such geometry as this from that period when a field for instance was 'a morning's work,' and a barn contained 'so many loads.'

§ 11. One or two glimpses of Egyptian geometry are obtainable at far later times. Democritus (*cir.* 460-370 B.C.) is quoted by

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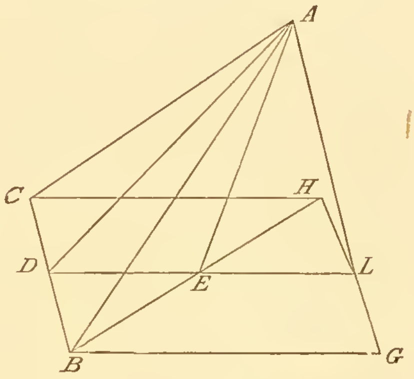
[1] The true value is 3·1415926535 . . . etc. This ratio has been calculated to more than 700 places of decimals.

Clement of Alexandria as saying, 'In the construction of plane figures (lit., composition of lines) *with proof* (the italics are our own), no one has yet surpassed me, not even the so-called *Harpedonaptae* of Egypt.' It was, of course, at first supposed that these *Harpedonaptae* were famous geometers, but Professor Cantor has pointed out that their name is compounded of two Greek words, signifying 'rope-fasteners,' or 'rope-stretchers;' and he explains their functions in the following manner. The ancient Egyptians were very careful about the exact orientation of their pyramids and temples. Inscriptions and the researches of modern scholars tend to show that the N. and S. line was drawn by actual observations of circumpolar stars. The W. and E. line was therefore drawn at right angles to the other. Now, it appears from the practice of the famous Heron of Alexandria, and of the ancient Indians and Chinese geometers, that a very common method of securing a right angle between two very long lines was to stretch round three pegs a rope measured into three portions, which were to one another as 3 : 4 : 5. The triangle thus formed is, of course, as every student of geometry knows, right-angled. Moreover, the operation of 'rope-stretching' is mentioned in Egypt, without any explanation, at an extremely ancient period (Amenemhat I.), and there is but little doubt that it was by this method that the E. and W. lines of the famous Pyramids of Ghizeh were drawn. If this be the correct explanation, and but little doubt, if any, remains, I think that it is; then the ancient Egyptians were acquainted more than 3000 years before our era with the geometrical propositions familiar to us as Euclid i. 47, 48, or, at any rate, with one particular case of them.

§ 12. This explanation of Professor Cantor's is, of course, a most ingenious one; still, it does not explain why Democritus should have used the words 'with proof.' And we might still suppose that he was alluding to some school of famous Egyptian geometers, descendants of the illustrious 'rope-stretchers' of old, were it not for the fact that the temple of Horus, at Edfu, in Upper Egypt, bears some inscriptions describing the lands which formed the endowment of the priestly college attached to the temple. The lands were given by Ptolemy XI., who reigned 107-88 B.C., but the geometrical descriptions of them, made 200 years since Euclid died, not only do not show a more advanced state of geometrical learning that the ancient Egyptians possessed in the time of Ahmes, but would cause even Ahmes himself to blush for shame. The reader will remember (§ 10) that Ahmes uses the incorrect formula $\frac{ab}{2}$ for the area of an isosceles triangle (using also the incorrect formula a $\left(\frac{b_1 + b_2}{2}\right)$ for that of an isoscles-parallel-trapezium). The inscription on the temple at Edfu retain both these, and use the second for finding the areas of trapezia of every kind, no matter how irregular. The dulness, laziness or carelessness of this proceeding is monumental in more senses than one. Such is an account of geometry as practised amongst the ancient Egyptians; the further we go back in their history, the more geometry they appear to know. The reason, we think, is not difficult to find; geometry, arithmetic, astronomy, land surveying, etc., along with writing, medicine, and the other useful arts, was in the monopoly of the priestly caste, who were the slaves of tradition, and who, in their obstinate and ignorant conservatism, appear to have been afraid to alter the rules or extend the knowledge of their craft. Concerning the art of medicine as practised among them, Diodorus (i. 82) expressly states, that even in his time the Egyptian doctors used only the recipes and prescriptions contained in the most ancient sacred books, lest they should be accused of murder or manslaughter in case the patient died. The science of geometry appears, most unfortunately, to have been treated with a like timidity.

§ 13. Lastly, this papyrus of Ahmes contains (Nos. 56-60) some examples seeming to imply a rudimentary trigonometry. In these, except the last, the problem is to find the *uchatebt*, *piremus* or *seqt* of a pyramid or obelisk. *Uchatebt* means, apparently, 'search for the base,' and is evidently a line which has something to do with the base; *piremus* apparently means 'result' (or issue) 'of the saw,' and is a line which can be obtained only by a section of the pyramid; *seqt* apparently means 'relation,' or 'like-making,' and is a number. For the purpose of these problems, the *uchatebt* is always halved. By means of these clues, Professors Eisenlohr and Cantor have explained in a most ingenious (not to say, I think, satisfactory) manner the purport of Ahmes' examples. In the accompanying figure of a pyramid, *uchatebt* may be either 2 DE (*i.e.*, DL) or 2 BE (*i.e.*, BH); the *piremus* may be either AD or AB, according as the pyramid is cut parallel with the base-line, or along the diagonal of the base square. The problems which Ahmes proposes for solution are always of the form,—'Given any two of the *uchatebt*, *piremus* and *seqt*, to find the third,' and he always obtains the solution from the fact that the *seqt* is half the *uchatebt* divided by the *piremus*. In the accompanying figure the *seqt* is $\frac{DE}{AD}$



or $\frac{BE}{AB}$, *i.e.*, in the language of modern trigonometry, *cos* ADE or *cos* ABE. The actual *seqt* given by Ahmes is in one case 0·72, in three more 0·75. Now these are the cosines of the angles 43° 56′ 44″ and 41° 24′ 34″ respectively. And the angle ABE in most existing pyramids is very nearly of these measurements; and moreover, these cosines of ABE correspond to angles of 53° 44′ 7″ and 51° 16′ 40″ respectively at ADE, and these are nearly the slopes of most existing pyramids; the slopes of the famous 'Great Pyramid' at Ghizeh being between 51° 49′ and 51° 51′. This fact is worthy of careful notice, being corroborative evidence, as it is, that Ahmes' papyrus, or rather the original from which Ahmes copied, was written *prior* to the building of this famous pyramid.

§ 14. The real import of these *seqt* calculations of Ahmes (which are, of course, in his work only exercises in arithmetic), appears to be as follows. The *seqt* or ratio between the distance of a ship and the height of a watch-tower (for instance) is the same as that between the corresponding sides of any small *similar* triangle.

Now, Eudemus tells us that Thales invented a mode of finding out the distance of a ship at sea, by apparently the following means :—ascend a tower of *known* altitude, and observe the angle which the ship subtends at the top of the tower, and then, by drawing on land a triangle equiangular or similar to this, the distance of the ship is (theoretically) known. This discovery of Thales would therefore appear to be of Egyptian origin. Another practical application attributed to Thales and depending on these same propositions (now familiar to us as Euclid i. 26, and vi. 4), viz., that of measuring the heights of pyramids and similar edifices by measuring their shadows at that hour of the day when a man's shadow is of the same height as himself; or by placing a staff vertically upright in the ground and measuring its height and the lengths of its shadow and that of the pyramid, you have the height of the pyramid or building, from the fact that 'the height of the pyramid is to the height of the staff as the length of the pyramid's shadow is to the length of the staff's.' This is obviously only another *seqt* calculation, in all probability derived by Thales from the ancient Egyptians.

§ 15. Such was the science of mathematics as studied amongst the ancient Egyptians in the valley of the Nile, in the time of the Pyramid kings, and under the reign of the Pharaohs. Very meagre and imperfect it no doubt appears to thee, oh reader! but remember that these *seqt* calculations of Ahmes led in later years to the science of trigonometry; and his *hau*-calculation to that of algebra. Remember that Egyptian (Chaldean) mathematics, such as they were, were eagerly studied by the earliest Greek geometers, and that they were the sparks which kindled that torch which lighted the sciences to their earliest discoveries, revealing as they did to man the world of form and the hidden secrets of number and figure and enlisting lines, curves and angles in the eternal service of man. Remember that they were the foundation stone of that magnificent science of geometry, that science which was the first to attain anything like a perfect form, and which had climbed far up the great mountain of truth, almost before any of the other sciences had commenced the ascent, and which beckoned from aloft for the others to follow in her footsteps, and to which every Englishman is indebted for his first lessons in right-seeing and right-thinking.

§ 16. In concluding this portion of my subject, it remains only for me to cite the universal testimony of the Greek writers as to the fact of Egypt being the birthplace of geometry, and to give a short account (in so far as such an account is possible) of the *evolution* of geometry. Herodotus, Plato, Diodorus, Strabo, Clemens of Alexandria, Jamblichus, and others all ascribe the origin of geometry to changes which annually took place in the land of Egypt from the overflowing of the Nile.

Herodotus says:—'I was informed by the Priests of Thebes, that King Sesostris made a distribution of the territory of Egypt among all his subjects, assigning to each an equal portion of land of a rectangle (or square) shape, and that from these allotments he used to derive his revenue by exacting every year a certain tax. In cases, however, where a portion of the land had been washed away by the annual inundations of the Nile, the proprietor was permitted to present himself before the king, and signify what had happened. The king used then to send proper officers to examine and ascertain by exact measurement how much of the land had been washed away, in order that the amount of the tax to be paid for the future might be proportioned to the land which remained. Hence, in my opinion (*δοκεέι δέ μοι*),' he continues, 'arose geometry, and from thence it was transmitted into Greece.' This same account is elsewhere repeated as legendary, without any reference to Herodotus, and it is probable that it was an Egyptian tradition which Herodotus appropriated. This account of the origin of geometry is sometimes scouted; nevertheless, I must think that it is, in the main, a true one, with the exception of the fact that Herodotus was most probably wrong in limiting its commencement to the reign of Sesostris, both the papyrus of Ahmes and other remains of ancient Egyptian science tending to show that its origin was very much more ancient. That his account contains some germs of truth is possible, I think, from the following reasons.

§ 17. What is geometry? It is the science of space, whether linear, superficial or solid, and it investigates the relations which exist between different parts of space. Now, some of these relations are obviously capable of arithmetical expression. For linear measurement, some measurement of the human body has universally served; the *finger-breadth*, *ell*, *palm*, *fathom*, *foot*, *span*, etc., have been, and still are, all the world over, units of length. Distances too great to be easily accurately ascertained were, in ancient times, measured by some reference to human capacity, as 'a stone's throw,' 'within shouting distance,' 'a day's journey,' 'seven days' riding,' etc. *But* the human body does *not* furnish any convenient unit of *area* or *solid contents. Large* areas and volumes were like long distances, in early times, roughly described by reference to labour; a field, for example, being a '*morning's work*,' or 'a day's work for a yoke of oxen;' and a barn was said to contain so many loads; small volumes being in all probability described by weight. How small *areas* were described we do not know, and there is therefore a gap in the history of geometry, which no writer has as yet succeeded in filling up. Again, the oldest extant geometry (that of Ahmes', just alluded to) is concerned (as we have seen) with the measurements of various areas or solids by reference to a *square* or a *cubical* unit. Why these particular shapes are selected in preference to several others which, *prima facie*, would do just as well, is not stated. Their selection implies, however, a long period of observation and consideration. The square and cubical units were certainly suggested by some figures in Nature or Art, most probably by the aspect of stone and brick buildings subsequent to the Cyclopean era of Architecture. But *the* question is not this, but why and how was man led to examine the properties of different figures, to investigate the peculiarities of certain angles?[1] The statement of Herodotus quoted above gives us, I think, the key to this enigma. Suppose that lands were originally in semi-primitive times measured roughly by their produce or by the labour required upon them, then the *first* attempt at an exact *numerical* measurement of their respective areas would be, I think, the measurement of their respective boundaries or *peripheries;* a method useful enough, and approximately correct so long as the areas were of nearly the same shape. But in process of time areas of one shape were exchanged for areas of another shape, and it was then for the first time discovered that figures of equal periphery were not necessarily of the same area. Let us suppose, for instance, that a man exchanged a *square* plot of ground measuring 100 yards round, for another plot of ground measuring the same distance round, but being 40 yards long by 10 broad. Then while the area of the first is 625 square yards, the area of the second is only 400 square yards, as every schoolboy now-a-days would at once know. A man having a square field exchanged it for a rectangle or rhombus of equal periphery, but found that he obtained less produce than heretofore. A discovery of this kind would call attention to angles and lines, and suggest the propriety of establishing a unit of area. The theory here set forth has the auxiliary of many facts in its favour. Areas in early times of the same periphery were, we know, often thought to be of the same area, and lastly, the word 'geometry' (γεωμετρια) means 'land-measurement,' in the same manner as the Egyptian *hunu* means 'land-measurer,' 'geometer.'

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[1] How much may not the geometrician of old time have learnt from the SPIDER and its web? 'Thou has seen,' said the Hindus, 'the spider spin its web—thou has seen its excellent *geometrical* form, and how well adapted it is for use.' It perhaps gave to man the first idea of how to determine the area of a circle, and thence higher curves. The Bee is, too, a perfect geometer, just as the Ant is a wonderful engineer. Architecture, too, in its most superb forms, is found in the exquisite structure of many a bird's nest.

§ 18. In concluding this account of the science of mathematics as studied amongst the ancient Egyptians, I cannot forbear just alluding to that question which in one sense lies at the bottom of all others, and which throughout almost all time has had an especial attraction for reflective minds, namely: What was the origin of mathematical ideas? Are we to regard them as independent of or dependent on experience? 'If we take the case of the individual,' says Professor Spottiswoode, 'all we can do is to give an account of our own experiences, how we played with marbles and apples; how we learnt the multiplication table, fractions and proportion; how we were afterwards amused to find that common things conformed to the rules of number; and later still, how we came to see that the same laws applied to music and to mechanism, to astronomy, to chemistry, and to many other subjects. And then, on trying to analyse our own mental processes, we find that mathematical ideas have been imbibed in precisely the same way as all other ideas, namely, by learning, by experience, and by reflection.'

And as it is with the individual, so I think we have already shown in this chapter was it with the ancients of old time, and if it be asserted that there is a difference between a mathematical assertion and one of another kind, as for example, if we say that a piece of iron unsupported falls to the ground, we make an assertion, the truth of which is evident, in the same manner as of another proposition, 'that two straight lines cannot enclose a space.' But that in the former statement an exception, or even a permanent alteration of the laws conceivable by the imagination, but that in the latter we are sensible of the absurdity of the idea if we attempt to construct or imagine the idea of an enclosure bounded by only two straight lines. The distinction exists only, I think, in the difference of the ideas themselves, from the preponderance of quantitative over qualitative considerations in mathematics. And, moreover, that the axioms lying at the basis of Euclidean geometry are not only conceivable of, but may, in course of time, undergo modification, as our ideas of the Universe expand, is seen by the criticism which this old geometry has had to undergo in the hands of Lobatcheffsky in Russia; Bolyai in Hungary; Beltrani in Italy; Gaus, Riemann in Germany; and Cayley, Sylvester and Clifford in England. But considering the universality of its laws, and remembering how *number* is a principle common to practically all branches of learning, it is not surprising, I think, that it became, even in early times, clothed in mysticism, or that even in modern times it was at first like the philosophy of Kant, placed upon an *a priori* basis.

'So wisely was medicine managed by them (*i.e.*, the ancient Egyptians) that no doctor was permitted to practise any but his own peculiar branch. Some were oculists, who only studied diseases of the eye; others attended solely to complaints of the head; others to those of the teeth; some again confined themselves to complaints of the intestines; and others to secret and internal maladies; accoucheurs being generally, if not always, women.'—HERODOTUS.

CHAPTER III.

MEDICINE.

> 'O Virgin, daughter of Egypt, in vain shalt thou use many medicines, for thou shalt not be cured.'—JEREMIAH.

§ 1. THE poet Homer has praised the skill of the Egyptian's physicians, and no sooner did the Persian kings become masters of Western Asia than they had recourse to Egypt for their medical advisers. The reader will perceive from this that the art of medicine amongst the ancient Egyptians was one held in high repute by neighbouring nations.

§ 2. From the very earliest times anterior to all written history, the art of medicine was cultivated by the ancient Egyptians. The principal method adopted by them for the prevention of illness was one which certainly had 'Common Sense' (termed by Guizot the 'genius' of humanity) to recommend it. 'Being persuaded that the majority of diseases proceeded from indigestion and excess of eating, they had frequent recourse to abstinence, emetics, slight purgatives, and other simple means of relieving the system, which some were in the habit of repeating every two or three days.' 'Those who live in the corn country,' as Herodotus terms it, 'were particular in their attention to health.' 'During three successive days they submitted to a regular course of treatment, from the conviction that illness was wont to proceed from some irregularity in diet, and if preventives were ineffectual, they had recourse to suitable remedies, adopting a course of treatment very similar to that described by Diodorus in paragraph three. The employment of various drugs in Egypt for the prevention of disease is mentioned by both sacred and profane writers, and the medicinal properties of many herbs which grow in the desert, more particularly between the Nile and the Red Sea, are still known to the Arabs, though their application appears to have been but imperfectly recorded and preserved. The ancient Egyptian doctors most probably felt the pulse, as Plutarch shows that they did at Rome from the saying of Tiberius, 'A man after he has passed his thirtieth year, who *puts forth his hand* to a physician, is ridiculous;' from which saying is derived in all probability our proverb: — 'A fool or a physician at forty.' Their prescriptions were made out in precisely the same manner as those of a modern doctor, and the various diseases were carefully distinguished from one another, and their symptoms minutely described, as well as their treatment. Some of these prescriptions have been derived from a fashionable *oculist* of Byblos, but the greater number belong to earlier Egyptian medical men, some of whom appear to have flourished during the first dynasty, and a medical work mentioned in the Berlin papyrus is said to have been first composed in the reign of the predecessor of King Sent of the second dynasty. The oldest medical papyrus that we possess (the Papyrus Ebers) does not, however, mount back further than the eighteenth dynasty. At that time the art of *medicine* in Egypt had most certainly reached the zenith of its fame, and was, perhaps, in quite as advanced a state (anatomy and physiology excepted) as in the age of the memorable Galen, 130 A.D.

§ 3. The medicines used were of four kinds—viz., draughts, blisters, powders and clysters — minerals as well as vegetables being employed in their composition. But progress in the art of medicine was checked and rendered well nigh impossible in the age of the Middle Empire and later times, by the rule — That all *new* medical treatment adopted by the doctors and physicians was done so at the risk of their being put to death in case the patient died. 'The art of medicine, as practised by them,' says Diodorus, 'was founded on written precepts, drawn up and transmitted by a great number of celebrated ancient doctors. If, on following the precepts of the ancient book, they were unable to save the patient, they were declared innocent and exempt from all reproach; but if, on the other hand, they acted contrary to the written precepts, they were liable to be accused and condemned to death, the judge being of opinion that few men would be likely to discover a better method of cure than that observed for so long a time, and established by the best men in the art.'

The reader will at once perceive from this, that any 'progress' in the science of medicine among the ancient Egyptians was, practically speaking, an impossibility; and he will also be somewhat prepared, I have no doubt, for the somewhat curious, and certainly very often extraordinary, views held by them relative to anatomy and physiology recorded in the following paragraphs.

§ 4. First, then, with regard to ANATOMY, and which, according to Manetho, was studied in the very earliest times; and Tosorthos or Athothes, the second king of Egypt, was said to have written a treatise on the subject. From the remains of this science left us by them, it certainly does not appear to have been nearly so far advanced as the art of medicine (in sit clinical sense, that is). In fact, the very nature of the anatomical theory held by them at once shows that this science was still in its infancy amongst them. According to this, 'the breath was drawn from the breast to the head, through thirty-two channels or veins, and thence transmitted to the limbs.' The *dissection* of the body amongst the ancient Egyptians—except in so far as it was necessary for the purpose of embalming—was, we know, viewed with peculiar abhorrence.[1] And thus, holding as they did these views with regard to the dissection of the body, it is not easy to see how their anatomy could be, in any sense, scientific.

§ 5. Similarly with regard to their PHYSIOLOGICAL views; they were like those held by them on anatomy, purely imaginary, not to say absurd. They appear to have imagined the body animated by a kind of *vital breath*, emanating from the heart, the primordial organ, which they elsewhere confounded with the lungs.

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[1] Pliny states (H. N., xix. 5) that *post mortem* examinations were allowed and even commanded by royal authority. There appear, however, to be no grounds for this statement.

§ 6. Sir J. Gardner Wilkinson and some other Egyptologists have stated that 'the ancient Egyptian dentists had adopted a method, not very long practised in Europe, of stopping teeth with gold, proofs of which have been obtained from some mummies at Thebes. Sir G. Wilson has, however, disputed this statement, and so, for the present, it must be set aside as 'not proven.' And, with regard to the setting of bones, etc., some mummies have been found with broken bones undoubtedly grown *naturally* together. It is quite possible that the ancient Egyptians possessed some knowledge of bone-setting and dentistry, though it would, no doubt, be somewhat primitive in its operations—the latter probably somewhat resembling the following very graphic account of Sir Henry Layard's experience of modern Oriental dentistry:—'I had slept,' he says, 'but little, as I was suffering greatly from toothache. The sheik declared that there was a skilful dentist in the encampment, and, as the pain was almost unbearable, I made up my mind to put myself in his hands rather than endure it any longer. He was accordingly sent for. He was a tall, muscular Arab. His instruments consisted of a short knife or razor, and a kind of iron awl. He bade me sit on the ground, and then took my head firmly between his knees. After cutting away the gums, he applied the awl to the roots of the tooth, and, striking the other end of it with all his might, expected to see the tooth fly into the air. But it was a double one, and not to be removed by such means from the jaw. The awl slipped, and made a severe wound in my palate. He insisted on a second trial, declaring that he could not but succeed. But the only result was that he broke off a large piece of the tooth, and I had suffered sufficient agony to decline a third experiment.'

§ 7. As time passed on, the art of medicine amongst the ancient Egyptians, like their mathematics and other sciences, does not appear to have improved, as one would naturally expect. In the latter days of Egyptian history, magical formulae and exorcisms, and a belief in the efficacy of dreams and supernatural agencies, began to take the place of the older (and undoubtedly better) medical prescriptions. Diseases were referred to the malignity of evil spirits, and the priest and sorcerer superseded the doctor and physician, as in earlier times they had been their predecessors. A demotic papyrus at Leyden of a later date is almost wholly concerned with charms, especially love philtres. The reputation, however, obtained by them in the art of healing still, however, continued, and for many centuries invalids and sick persons still had recourse to them from almost every clime.

Though the ancient Egyptians deteriorated so much in the art of medicine in later times (prior, however, to 300 B.C.), in early times their knowledge of this science was probably in advance of that of the Greeks. *Aristotle*, we know, held that the blood was essential to the body, but insensible in itself and the element of nutrition, essential also to the activity of the soul, that the brain was *not* the recipient of sensations, that function belonging to the heart, all the animal activities being united in that organ; that it contained the principle of life, it being the first formed and the last to die; that the brain was a mere appendix to the heart, it being formed after that organ; that it was the coldest of the organs, being devoid of blood. The reader will perceive from this that Aristotle's anatonomical and physiological views were but little, if any, in advance of the ancient Egyptians. The Greek *Hippocrates* (400 B.C.) has, we know, been termed the Father of Medicine, and as a physician who strenuously endeavoured to wrest the medicine of his time from the influence of sorcerers, wizards and priestcraft, and found it upon the pure basis of observation and experiment, he justly deserves that name. Owing, however, to the non-permittance among the Greeks (as among the ancient Egyptians) of the dissection of the dead, his anatomical, physiological and pathological views were very erroneous. And it is an open question whether his clinical knowledge was in advance of that of the ancient Egyptians as early as 3000 or 4000 B.C. The real foundation of the science of medicine was undoubtedly laid by the Alexandrian school, where dissections and vivisections were first practised.[1]

§ 8. Certain members of the medical profession appear to have undertaken the far-famed process of Egyptian embalming, and we therefore conclude this chapter with a brief account of the means employed by them for preserving their illustrious dead. They employed *three* methods of embalming, of which we give one — the most elaborate, effective and costly; the other two were similar, but not so elaborate. Our account is taken from Herodotus, who says :—' In preparing the body according to the first method, they commence by extracting the brain from the nostrils by means of a curved iron probe, partly cleansing the head by these means, and partly by pouring in certain drugs; then making an incision in the side *with a sharp Ethiopian stone*,[2] they draw out the intestines through the aperture. Having cleansed and washed them with palm wine, they cover them with pounded aromatics; afterwards, filling the cavity with powder of pure myrrh, cassia, and other fragrant substances, and frankincense, they sew it up again. This being done they *salt* the body, keeping it in natron during 70 days, to which period they are strictly confined. When the 70 days are over, they wash the body, and wrap it up entirely in bands of fine linen[1] smeared on the inner side with gum, which the Egyptians generally use instead of glue. The relations then take away the body,' etc.

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[1] See Part II., ch. i., note.

[2] This, apart from anything else, shows the antiquity of the process. The low-caste official whose duty it was to do this (since all in Egypt who mutilated the dead were held in abomination) used to make the best of his way into the country (pursued with stones, sticks and curses), and there

The reader will perceive, from this account of Herodotus, that the Egyptian of old time was, strictly speaking, more *salted* than embalmed, and he will also see the absurdity of speaking of their embalming process as one of the most wonderful of the lost arts.

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remain till the storm had blown over. He was the original, it is said, of the familiar phrase to *cut* and *run*. The *cost* of ancient embalming was about £244. The modern method cost about £50, and the time taken by the entire process is only a few hours, besides being so much more effective.

[1] Which now-a-days the pilfering Bedouins use for cloths and sell for paper.

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ENGINEERING! that science which embraces the design and execution of every work by which Commerce and the practice of the useful arts may be best facilitated. That science by whose aid embankments have been raised to resist the never ceasing encroachments of the ocean; and land which may have been already covered reclaimed. That science which has rendered rivers navigable and mountains passable, and by whose aid docks or artificial harbours have been made, where ships may remain in security; and which has enabled man to penetrate, by mines, to vast depths for the purpose of seeking the mineral treasures contained in the bosom of the earth. And which turns a sunken rock, on which whole fleets of ships have, in century after century, been wrecked, into the foundation of a beacon or a lighthouse; and which so tunnels a mountain or a sea, that men may dive beneath what seems to separate them, and be neither crushed by rocky masses nor overwhelmed by the deep.

CHAPTER IV.

ENGINEERING.

'Well the primal pioneer
Knew the strong task to it assigned,
Patient through Heaven's enormous year
To build in matter home for mind.'—EMERSON.

§ 1. CONTRARY to their achievements in the science of medicine, the engineering attainments of the ancient Egyptians are both great and surprising. Their engineering science is certainly most remarkable, and has never been, in some respects, surpassed. 'In the cutting of hard materials, the polishing of surfaces, the exact production of any angle required, and the power of quarrying, this ancient people,' says Rawlinson, 'was, and still is, unsurpassed.'

The results attained by them in the science of stone-cutting have been with reason declared equal to those accomplished at the present day by the aid of gunpowder and steam machinery. In mechanical skill, their great works are as perfect as anything that has ever been produced since. ‘No one can possibly examine the interior of the Great Pyramid,’ says Mr Ferguson, ‘without being struck with astonishment at the wonderful mechanical skill displayed in its construction. The immense blocks of granite brought from Syrêne, a distance of 500 miles, polished like glass, and so fitted that the joints can scarcely be detected. Nothing can be more wonderful than the extraordinary amount of knowledge displayed in the construction of the discharging chambers over the roof of the principal apartment, in the alignment of the sloping galleries, in the provision of ventilating shafts, and in all the other wonderful contrivances of the structure. All these, too, are carried out with such precision that, notwithstanding the immense superincumbent weight, no settlement in any part can be detected to the extent of any appreciable fraction of an inch. *Nothing more perfect, mechani-*

cally, has ever been created since that time.'[1]

§ 2. In massiveness of structure, the engineering achievements of the ancient Egyptians far exceed all that any other nation has since attempted. Consider, for example, the largest of the Pyramids of Ghizeh, whose original height was somewhat over 480 feet, and the length of each side, at the base, 764 feet, and whose cubical contents exceeded 809,000,000 cubic feet, and the weight of whose mass was 6,840,000 tons. In height, therefore, it exceeded Strasburg Cathedral by more than 6 feet; St Peter's, at Rome, by more than 30 feet; and St Paul's, London, by 120 feet. The area which its base covered was 13 acres, 1 rood, and 22 poles, or, in other words, its base covered an area nearly equal to Lincoln's Inn Fields. Its cubic contents would have built a city of twenty-two thousand houses, with solidly built walls a foot thick, possessing 20 feet of frontage, and 30 feet of depth from back to front; the walls having a height of 24 feet and a foundation of 6 feet; and, in addition to this, the building could possess party walls to one-third the extent of the main wall. Or suppose that the contents of this vast structure were laid down in a line a foot in breadth and depth, this line could be nearly 17,000 miles in length, a girdle two-thirds of the earth's circumference at the equator. Herodotus tells us that one hundred thousand men were engaged in its construction for a space of twenty years, working continuously, and modern scholars do not regard his estimate as exaggerated. In respect to its *mass*, at any rate, this building is '*the most prodigious of all human constructions.*'

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[1] 3400 B.C., *i.e.*, more than 5000 years ago.

The height of the Second Pyramid was only 33 feet less than that of the Great Pyramid, the length of each side at the base 57 feet less, and the area which it covered nearly two acres smaller. Its cubic contents would build a town of eighteen thousand such houses as described above; and if laid out in a line, the line would be 13,500 miles long. And lastly, supposing that a single man could quarry one ton of stone in a week, then it would have required about twenty thousand, to be employed without ceasing for five years, in order to obtain the material for this Second Pyramid; and if, moreover, in addition to this, the blocks were required to be large, then of course the number employed and the time occupied would have been much greater.

§ 3. The engineering student of to-day is lost in admiration when he contemplates the immense masses of stone so prodigally employed by the ancient Egyptians in their pyramids and their temples, their palaces and their tombs, using as they did blocks of stone 30 or 40 feet long either in walls or for the lintels of their doors. Obelisks weighing 200 or 450 tons each were of common ornamentation in the architecture of the ancient Egyptians, each one of which would be a wonder to the Western World. These immense obelisks were sometimes set up in *avenues*. Again, monolithic chambers and colossi weighing as much as 800 tons have been discovered, all of which appear to have been moved with ease to the spot required, as though there were no mechanical difficulties whatever in the transportation. In consequence of all this, the first travellers who visited Egypt in modern times arrived at the conclusion that the ancient Egyptians were peculiarly skilled in the *science* of practical mechanics. This is, *in one sense,* a pure illusion. The great secret of the ancient Egyptians no doubt lay *in their unlimited command of individual labour,* and the unflinching manner in which they made use of it. Multitudes were employed upon a single building, and made to labour at its construction by the rod of the overseer until it was finished. Their chief method of conveying huge masses of stone was by placing them upon rafts (buoyed up often by inflated skins) at the foot of the mountains in which they were quarried, and then floated down rivers and artificial canals to a point as near as possible to their destined sites. They were then placed upon a kind of huge wooden sledge, to which hundreds of men were (figuratively speaking) 'harnessed,' and dragged over well-oiled wooden causeways to the building of which they were to form a part. They were then raised to the required height by resting them upon two piles of wooden slabs and rocking them (by means of levers, etc.) up alternately to one side and the other, thus gradually heightening the piles. The ascent of the Pyramids of Ghizeh were, we know, raised from step to step by these means, and Herodotus has given a description of a machine made of short pieces of wood, which does not seem to be explainable in any other manner than the above.

§ 4. This view of their mechanical science is corroborated, too, by the writings of other classicians, and such representations as the ancient Egyptians have left us of their methods of proceeding are all calculated to support this view. Human muscle was their great motive power, and scarcely any mechanical art or expedient appear to have been employed to facilitate the operations of transportation, raising, etc. No levers, or only those of the very rudest kind, were, as far as we know, made use of, nor rollers; beyond the rounding off the front of the wooden sledge, whereon the colossi, etc., were placed, and, as already mentioned, the lubricating of the ground over which it had to be dragged by some oily substance, no ingenious contrivances appear to have been made use of. Sheer strength achieved the object aimed at, accomplished, we know it must have been, slowly, painfully, with much waste of power, and often attended with horrible accidents. That it was accomplished slowly and painfully we know from the statement of Herodotus, who tells us that it took *three years* to convey a certain monolith from the quarries of Elephantiné to Siriïs in the Delta, *two thousand* men being employed in effecting the transport. That horrible accidents were by no means rare is certain from the means employed by them to effect the transportation and setting up of the enormous masses, and Herodotus also tells us with regard to the monolith already alluded to, that it was out of its place, and that it was said that one of the workmen engaged in moving the mass was crushed and killed by it, and that that was the reason of its being left where it stood.

§ 5. That the ancient Egyptians were

acquainted with machines of some sort is certain; they may have been simple, or they may have been complex. As we have no representations of them, they not being anywhere represented in the Egyptian sculptures, it is therefore extremely difficult to determine their character in detail. What we *do* know about them amounts to this—they, *i.e.*, the builders of the pyramids at Ghizeh, besides being acquainted with the more simple instruments of the carpenter, mason and builder, were familiar with many tools which have been regarded as among the most recent triumphs of human invention. Mr W. M. Flinders Petrie has indubitably proved[1] that the workmen employed in their erection were acquainted with the use of circular cutters or saws, the cutting edge being set with gems, like the drills for slicing hard stones, fragments exhibiting well-marked circular scorings having been found. And with regard to the manufacture of stone bowls, Mr Petrie's researches seem to show that the turner of the ancient Egyptians was acquainted with the use of mechanical 'rests' for holding the turning tool.[1] These contrivances were usually supposed to be not older than the end of the last century. This subject is of too technical a nature for those unacquainted with workshop manipulation to be pursued further; but what a light do these discoveries throw upon the civilisation of the ancient Egyptians! They were also un-undoubtedly acquainted with the principle of the *Inclined Plane*, and made use of it in the erection of their temples and pyramids. The principle of the lever appears also to have been known to them, and also made use of in very early times. For the *Lever*, or to speak more correctly, the *Balance*, existed amongst them as early, at any rate, as the commencement of the Middle Empire (3000 B.C. *cir.*), and very likely much earlier. It was at first, of course, of rude construction; in course of time it was, however, more and more delicately made, the last models resembling our own in beam, platform and pillar.

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[1] *Vide* 'Engineering,' 22d June 1883.

They were acquainted also with the principle of the *Pulley*, for one has actually been found in Egypt, and is now in the museum of Leyden. It was apparently used for drawing water from a well. The sides are of tamarisk wood, the rollers of fir; and the rope of *leef*, or fibres of the date-tree, which belonged to it, was found at the same time. There is no direct evidence, it is true, that the ancient Egyptians used the pulley in their engineering works, in which sheer brute strength, the 'rocking machine,' and the lubricated surface, described above, appear to have almost solely made use of. It is hardly conceivable, however, that the raising into place of obelisks, the lintels of doors, and roofing blocks, such as those which cover the sepulchral chamber of the Great Pyramid, can have been entirely effected by such means as these. Whether they were or not, it is certain that obelisks of the largest size were placed upon their pedestals successfully, pyramids built up to the height of nearly 500 feet, temples roofed in with huge masses of stone quarried hundreds of miles away. Whatever were the means employed (and as far as the evidence goes they appear to have been only those cited above), the required ends were most certainly (in time) effected, and the lower the opinion we form of their mechanical appliances, the higher must be our admiration of the skill, perseverance and industry which, with such poor means, achieved such vast results.

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[1] They were also, from remote times, acquainted with the *potter's wheel.*

§ 6. The engineering achievements of the ancient Egyptians hitherto recorded are, however, by no means the greatest (in the true sense of the word) or the most important effected by them, for their huge pyramids and temples are monuments which, when rightly viewed, must be regarded not as objects which should excite our admiration, but as the most stupendous records of the length to which lust of power, tyranny and selfishness, folly and superstition will carry a man. No good whatever has resulted to any man from all the enforced labour, misery and expense involved in raising them. 'They are, and ever have been,' as a writer has observed, 'splendidly worthless.' They will probably endure when the destroying hand of Time has swept every other building from the face of the earth. Regarded as works of skill, and as examples of what man may effect by combined and long-continued labour, they are indeed marvellous, and must always in that one sense excite our admiration. But while these monuments of the ancient Egyptians are unsurpassable in one sense by any of the buildings of old time, we have the satisfaction of knowing that the more perishable efforts of our own time are not records of tyranny and selfishness, bigotry and superstition ; are not monuments of splendid worthlessness, but are records of the desire to increase the knowledge, advance the interests, and ameliorate the condition of the human race. Let us, then, in the remainder of this chapter, turn our attention to some constructions and engineering achievements of the ancient Egyptians, which are, I am thankful to say, by no means records either of tyranny or selfishness, but works which involved good instead of misery to the lowlier classes, and which have, in a very material way, indeed, increased the well-being of man.

§ 7. The engineering achievements of the ancient Egyptians, of which we now purpose to give a brief account, are none other than those by means of which they transformed what would have been nothing more than a barren desert into a land of plenty, and by means of which they helped to make Egypt the richest and most productive land in the world. I allude, of course, to those triumphs of engineering with regard to the cutting of canals and the making of artificial lakes or reservoirs, by means of which the precious fluid of the Nile could either be conveyed and poured on barren regions, or stored up in case of an insufficient inundation, to supply the deficiency resulting from this cause, and avert, in some measure at any rate, those awful disasters which always resulted from this cause.

These engineering triumphs date from the most remote antiquity. Herodotus says that Menes, who was the first of the Egyptian kings, and the founder of Memphis, found, on desiring to build that city, a difficulty in obtaining a site in all respects advantageous, because the river Nile, before debouching upon the plains, hugged the base of the Libyan hills for

Note.—Rameses II. caused his engineers to cut a canal from the Nile to the Red Sea, a work which cost the lives of 120,000 men, and countless treasures of money.

many miles, and was thus on the wrong side of the valley. It was wanted on the other side, in order that it might be a water bulwark, so to speak, against any Asiatic invader. Menes, therefore, before building his city, undertook a gigantic work. He raised an immense embankment across the natural course of the river, and thereby forcing it from its bed, he compelled it to enter a new channel and run mid-way down the valley, or, if anything, rather towards its eastern side. By these means he obtained the required bulwark against any Asiatic invasion, and was in possession of an ample site for his capital between the new channel of the river and the foot of the western hills.

§ 8. Another great engineering work undertaken by the ancient Egyptians, perhaps the greatest of their many mighty triumphs in that science, was that undertaken and accomplished by Amenemhat—'the good Amenemhat,' as he was most appropriately called by his subjects. The work undertaken by him was to supply the wants occasioned by a *deficient* inundation of the Nile, and prevent in some measure those awful famines which were, and alas still are, the result of such an occurrence. What he did to remedy these evils was as follows:—He dug a canal from the western branch of the Nile—the modern Bahr Yousuf—leaving it at El Lahoun, and carried his canal through the gorge, in places cutting deep into its rocky bottom, and by a system of sluices and flood-gates he retained such an absolute control over the water that he could either exclude or admit the inundation at his will as it rose; and when it fell, could either allow the water that had flowed in to return, or imprison it and keep it back. The exact size and position of his reservoir within the depression are not known with certitude. With regard to its size (which is of most concern to us here), M. Linant de Bellefonds considers the area of this artificial lake to have been about 405,000,000 square mêtres, or about 480,000,000 square yards. Mr Cope Whitehouse believes the lake to have been in places 300 feet deep, and that the circuit of its shores was from 300 to 500 miles. Whichever estimate may be right concerning this 'Lake Mœris,' as it was called, there is no doubt it was a grand construction, undertaken mainly for the benefit of the people, and that it greatly contributed to their welfare.

§ 9. The ancient Egyptians appear to have made, even in very early times, considerable advances in Naval as well as in Military and Civil Engineering. For, from a very remote period, they possessed ships, some of which were of great size. Diodorus mentions one of cedar wood, dedicated by the celebrated Sesostris to the god of Thebes, of which the length was 280 cubits, or 420 feet. And the famous Queen Hatasu,[1] the daughter of the great warrior king, Thothmes the First, on forming her grand ideas of foreign commerce, caused a fleet of ships, of certainly not a less number than five, to be built, each constructed so as to be propelled either by oars or sails, and each capable of accommodating from sixty to seventy persons.

§ 10. Such is a brief account of the engineering achievements of the ancient Egyptians, and of the skill possessed by them in that science *more than five thousand*

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[1] Whose throne is actually at the present time in the British Museum.

years ago; and who could, even at that period of the world's history, build pyramids and temples, raise obelisks, dig canals, and make artificial lakes such as have, in point of size at any rate, never been surpassed. In reading this account of their early triumphs in this science, let us remember that it was not until the year 1760, or only a little more than *one hundred* years ago, that the *first* canal was cut in England, and that up to that time, did we require an engine to pump water from the Thames, our fens draining, a new haven building, or even a new bridge building across our chief river, it was either a Dutchman or a Swiss who executed the work; whilst our roads were at that time about the worst in Europe. Engineering in England can scarcely be said to possess a past, whilst amongst the Egyptians it possesses a past in the dim vista of which its origin is lost. All thanks and honour, then to those who first,—

> Made Harbours open, Public Ways laid down;
> Made Temples, Palaces and Pyramids o'er the
> desert frown;
> Made the firm bank the dang'rous flood contain;
> And rolled obedient rivers o'er the plain.

'IN such untoward times, it was perhaps needful that the strongest passions of men should be excited and stimulated by inquiries for methods of turning lead into gold, or of prolonging life indefinitely. We have now to deal with the philosopher's stone, the *elixir vitae*, the powder of projection, magical mirrors, perpetual lamps, the transmutation of metals. In smoky caverns underground, where the great work is stealthily carried on, the alchemist and his familiar are busy with their alembics, cucurbites, and pelicans, maintaining their fires for so many years that salamanders are asserted to be born in them.'—J. W. DRAPER.

CHAPTER V.

CHEMISTRY.[1]

'Magic, and all that is ascribed to it, is a deep presentiment of the powers of science.'—EMERSON.

§ 1. That the ancient Egyptians possessed considerable knowledge of many of the practical applications of chemistry, and the use of metallic oxides, is perfectly clear from the nature of the colours applied by them in their porcelain and glass, and they were also acquainted with the influence of certain acids upon colours, for they were able, in the process employed by them for the dyeing or staining of cloth, to bring about certain changes in the hues, in precisely the same manner as is now done in our own cotton works. This is proved by a statement of Pliny, from which account, while we at once perceive from its perusal how little he understood the process he was describing, he, at the same time, gives us the strongest evidence of its truth. His account is as follows:—'In Egypt they stain cloths in a wonderful manner. They take them in their original state, quite white, and imbue them, not with a dye, but with certain drugs, which have the power of absorbing and taking colour. When this is done, there is still no appearance of change in the cloths; but as soon as they are dipped into a bath of pigment, which has been prepared for the purpose, they are taken out properly coloured. The singular thing is, that though the bath contains only one colour, several hues are imparted to the pieces; nor can the colour be afterwards washed off; and surely, if the bath had many colours in it, they must have presented a confused appearance on the cloth.' From this account of Pliny's, it is evident that the cloth was previously prepared by steeping; and the *momentary* effect he mentions could only have been produced by the powerful agency of *mordants;* and it shows, in addition to this, that the ancient Egyptians not only used them to make the cloth take the colour equally, but also to change the hues.

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[1] The modern words Chemistry and Chemist are derived from the old name Cham or Chemia for Egypt. Men, reflecting that this was the old name of this country, were pleased to call their art the art of the ancient Chemi. Alexander of Aphrodisia previously to this had invented the word *chymike* to describe the operations of the laboratory. Hence the word *Chemics*, a word unknown in the fourth century, and only popular some centuries later.

§ 2. From these facts, the question which naturally arises is, Did the ancient Egyptians really understand the principle on which the salts and acids of the mordants acted, or did they calculate their effects solely from the experience they had in course of time acquired? This question, which is full of the deepest interest, is a very difficult one to decide. These same mordants were, in later times, used for a long time in Europe, before their chemical agency was explained. When the term mordant was first applied by the French dyers, they thought 'that the purpose for which the substances about to be dyed were passed through saline liquors was to corrode something that opposed the enter-

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Note.—The dawn of the *modern* science of chemistry dates, of course, from the time of Priestley, Cavendish and Lavoisier. Priestley discovered the existence of oxygen gas on 4th of August 1774 A.D.

ing of the colouring principle, and to enlarge the pores of the substances, the effect of acids in changing the hues being a later discovery. We cannot therefore prove, or infer, with any degree of certitude from these facts, that the ancient Egyptians possessed any knowledge of theoretical chemistry. Though some, no doubt, would not think it too much to infer, from their long experience and skill in the use of metallic oxides and mordants, that they must have possessed some knowledge of the subject, for it seems reasonable to infer that, though they were at first no doubt ignorant of the reason of such changes, some among them would, in the course of time, be led to investigate the process by which they were effected.

§ 3. We may therefore, I think, suppose that some general notions of certain portions of the science of chemistry, or at least of chemical agency, were known to the ancient Egyptians. The beautiful

Note.—The ancient Egyptians knew how to prepare beer from malted grain, and also wine from fermented grape juice. The story of the manufacture of fermented liquors is a very old one indeed, and as Professor Huxley has observed, 'amongst the earliest records of all kinds of men, you find a time recorded when they got drunk.'

colours that they obtained from copper, the composition of the various metals, and the knowledge possessed by them of the effects produced on different substances by the salts of the earth, all tend to confirm this opinion. What this knowledge was in detail, we of course at present do not know, though from the following facts some inferences may be drawn.

§ 4. The ancient Egyptians were, we know, intimately connected with the Chaldeans, who, with

> 'Their calendars and dials,
> Horoscopes and chemic phials,'

sought to discover the philosopher's stone, *not* by chemical investigations alone, but by carrying out such investigations under special celestial influences. And that the Egyptians were alchemists is a fact corroborated in many ways. The Arabian writer Ibn Abd Alkokm, speaking of the various contents of the different pyramids, says that King Saurid placed in the East Pyramid (*i.e.*, the Great Pyramid), not treasures, but 'divers celestial stars and spheres, and what they severally operate in their aspects, and the perfumes which are to be used to them, and the books which treat of these matters.' That alchemy was much practised amongst the ancient Egyptians there is now no doubt. Whether their researches in alchemy led them to the discovery of scientific truths is open to question. In the *Tractatus Aureus*, attributed to Hermes, is given the following directions for the preparation of the philosopher's stone, viz. :—To 'catch the flying bird' (*i.e.*, quicksilver, or mercury) 'and drown it, so that it may fly no more.' This is what is afterwards termed the *fixation* of mercury, by uniting it to gold. And so on, the result in the end being probably to *increase* the weight of gold by the addition of an impurity.

§ 5. It is worthy of careful notice, however, that the first alchemist of whom we have any really authentic account, viz., Geber, or Djafar (700 A.D.), is (if his writings be authentic) in possession of a chemistry very advanced indeed. He knew, in fact, how to perform many chemical operations, such as filtration, crystal-

Note.—NEBKA, the fifteenth king of the Abydos tablet, is said to have invented colours, and to have introduced into sculpture the additional adornment of painting.

lisation and sublimation, and was also able to prepare nitric acid or *aquafortis*, and from it the mixture *aqua regiæ*, a liquid almost fulfilling, at any rate, in its solvent properties, Van Helmont's dream of the *alcahest*, or universal solvent, and the only acid dissolving gold. It consisted of mixed nitric and hydrochloric acids. It appears almost incredible that Geber could have discovered all this himself, and borrowed nothing, or next to nothing, from those who went before him.

§ 6. However this may be, chemistry, even if only under the guise of alchemy, and in its practical applications, was extensively cultivated amongst the ancient Egyptians, and, as in its practical applications, it lead to many great and important results, so under the head of alchemy, though it never enabled them to achieve their golden, but unhealthy, dreams of the philosopher's stone, or the elixir of life, led to the discovery of nitric and sulphuric acid, many other chemicals, and much useful apparatus.

Modern chemistry is the natural offspring of ancient alchemy. For the object of both has been the same—the discovery of a changeless foundation of ever changing phenomena. The ancient alchemists dreamt of the philosopher's stone, which should turn all the baser metals into changeless gold; and of the elixir of life, the producer of a changeless condition of life, and laboured diligently to find them. Their endeavours were not, of course, successful, but they brought to light a knowledge which has enabled the modern chemist to find the elements, and beneath the elements to find the atoms, and beneath the atoms to sometimes think that they perceive the atoms of ONE element, of which all the known elements and compounds are but, it may be, developed forms.

'THE foundations of all natural knowledge were laid when the reason of man first came face to face with the facts of Nature: when the savage first learnt that the fingers of one hand are fewer than those of both; that it is shorter to cross a stream than to head it; that a stone stops where it is, unless it be moved, and that it drops from the hand which lets it go; that light and heat come and go with the sun; that sticks burn away in the fire; that plants and animals grow and die; that if he struck his fellow-savage a blow, he would make him angry, and perhaps get a blow in return, while if he offered him a fruit, he would please him, and perhaps receive a fish in exchange. When men had acquired this much knowledge, the outlines, rude though they were, of mathematics, of physics, of chemistry, of biology, of moral, economical and political science, were sketched.'—T. H. HUXLEY, F.R.S.

CHAPTER VI.

NATURAL PHILOSOPHY.

> 'An impulse inherent in primeval man turned his thoughts and questionings betimes towards the sources of natural phenomena.'—J. TYNDALL, F.R.S.

§ 1. IN speaking of the engineering triumphs of the ancient Egyptians, I have already called the reader's attention to the fact that they were acquainted with many applications of Practical *Mechanics;* and that such mechanical instruments as the Pulley, the Lever and Balance, the Inclined Plane, etc., were known to them from a very remote period. There is, of course, no evidence that they were acquainted with any of the laws of *Theoretical* Mechanics, or that they offered any explanation of the *principle* of the various machines used by them, or that they were led, from experiments made and results achieved by them in the science of

Practical Mechanics, to the foundation of any of its great laws.

§ 2. It was, as we have already pointed out to the reader, of the utmost importance to the agricultural pursuits of the ancient Egyptians, and to the interests of the peasant, to distribute the benefits of the inundation in due proportion to each individual — that those possessing low-lying lands might not enjoy the exclusive advantage of the fertilising waters by constantly draining it from those of a higher level. For this purpose they were obliged to ascertain the various elevations of the country, and to construct accurately levelled canals and artificial lakes. These canals or dykes were succeeded or accompanied by the invention of *sluices*, and all their accompanying mechanism. The regulation of the supply of water necessary to be admitted into the various plains of different levels, the reports of the *exact* quantity of land irrigated, the depth of the water in the various canals at different times, and the time during which the water remained upon the surface of the land, which determined the proportional payment of the taxes, required, of course, some scientific skill, which it no doubt in course of time considerably increased. The prices of the ensuing year were, we know, already ascertained by the unerring prognostics of the existing inundation. These facts led them, in course of time, to make careful observations of many things that would otherwise have escaped their notice; and it is to this same cause that must be attributed much of that practical skill of the Egyptians, both with regard to the sciences of Mechanics and Hydrostatics.[1]

§ 3. *Nilometers*, for measuring the gradual rise or fall of the Nile, were constructed in various parts of Egypt, certain persons being appointed to daily observe the changes and to proclaim the favourable or unfavourable state of this all-important phenomenon. On these reports depended the time chosen for opening the canals, whose flood-gates were kept closed until the river rose to a certain fixed height, upon which occasion grand festivities were proclaimed throughout the land, in order that every person might show his sense of the great benefits vouchsafed by the gods unto the people of Egypt. The precise date when Nilometers were first constructed, it is impossible to determine; but from the *height* of the inundation being already recorded in the reign of a king of the twelfth dynasty, we may infer that they had been invented previous to that epoch. With regard to the construction, etc., of these Nilometers, the celebrated one in the island of Elephantine is a staircase between walls descending to the river, on one of which is a succession of graduated scales. The graduations of the scales appear, however, to have been made with a characteristic carelessness peculiarly Egyptian.

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[1] In one sense, the debt of 'science' to the *Nile* cannot be over-estimated.

§ 4. *Siphons* are represented on the Egyptian monuments, and are shown to have been invented at as early a period, at any rate, as the reign of Amunoph II., occurring again in the paintings of Rameses III. In a tomb at Thebes (bearing Amunoph's name), their use is unequivocally pointed out by one person pouring a liquid into some vases, and the other drawing it off by applying the siphon to his mouth, and thence to a large vase. ‘It is not improbable,’ says Wilkinson, ‘that they owed their invention to the necessity of allowing the Nile water to deposit its thick sediment in vases, which could not be moved without again rendering it turbid, whether by inclining the vessel or dipping a cup into it with the hand. In later years they were used on a grand scale for draining lands and conveying water over a hill from one valley to another. Their name “siphon” is evidently oriental, and derived from the word *siph* or *sif*, “to imbibe,” or draw up with the breath,” analagous to, and most likely the origin of our modern word ‘to sip.’

§ 5. They had also invented the *Syringe*, which they used for injecting liquids into the head and bodies of their dead during the embalming process; and an instrument is often represented in their sculptures (more particularly of the early times) which has all the appearance of a portable *Pump*.

§ 6. The *Water Wheel* was not unknown to them, though they do not appear to have used it very generally, the *Hydraulic Screw* was also used by them, though this was probably a later invention. They appear, however, to have possessed the *Foot Machines* mentioned by Philo; and the following passage in Deuteronomy (xi. 40) probably refers to this,—'Egypt . . . where thou sowest thy seed and waterest with thy *foot* as a garden of herbs.' The common mode of raising water, employed from times of the remotest antiquity, was by means of the pole and bucket, or *shadoof*, so common in Egypt even now.

§ 7. The reader will at once perceive from the foregoing paragraphs that the ancient Egyptians had made considerable advances in the practical sciences of mechanics and hydrostatics; they were not, it is true, as far as we know, acquainted with any of the Laws of Statical Equilibrium, or of Motion, or of Atmospherical Pressure, or of the Equilibrium or Motion of Fluids; their knowledge was, no doubt, empirical and empirically obtained. Of the laws governing these phenomena they were, no doubt, ignorant; but we must always bear in mind that the foundation of Theory is *Practice*, that empirical or practical knowledge *must* be first cultivated in order to render Theoretical or Scientific Knowledge, which is only, after all, the accumulation of all Practice, possible. Had not the Egyptians, and other nations of antiquity, made these empirical discoveries, the analytical and reasoning mind of the Greek would never have found a foundation stone whereupon to commence the erection of that temple of (theoretical) science of which we are to-day so justly proud. And this fact should always be most carefully borne in mind during the perusal of an account relating the early discoveries of mankind.

§ 8. *Mirrors* were manufactured by the ancient Egyptians from the very earliest times, and they appear to have been acquainted with the simple laws of reflection relating to plain mirrors at even as early a time as that of the building of the Great Pyramid.[1] They were also possibly acquainted with the simple law of refraction, though *not* in connection with the position of the heavenly bodies. Arabian writers, in their account of the progress of the Egyptians in astrology and the mystical arts, relate that King Laurid, who built the first pyramids, invented also the '*magic*' *mirror.* Which probably means (if it means anything at all) a *convex* or *concave* mirror. There is no evidence, however, that they were acquainted with *lenses;* and that they were *not* (in early times at any rate) acquainted with the *Telescope* is evident from certain constructions effected by them for the orientation of their pyramids.

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[1] *Vide* Proctor's 'Great Pyramid,' p. 113.

§ 9. The origin of the science of *Electricity—the* science, *par excellence*, of to-day, is usually attributed to Thales, who is said to have been the first to observe that a piece of amber, on being rubbed with a piece of silk, possessed the curious power of attracting light bodies. Thales may or may *not* have been the first to observe this peculiarity (in all probability he was not), but the origin of the science of electricity must, in any case, be assigned to a more remote date, I think, than the epoch of Thales. Amongst the fishes of the Nile is one which possesses the power of giving an electric shock (by no means a slight one, as those know who have experienced it). 'It is a small fish,' says Wilkinson, 'and the one I saw was little more than a foot long, by four inches in depth.' This fish is scientifically known as the *Melapterurus Electricus*, and was in all probability the ancient *Latus*. Now the name of this fish is very remarkable; it is '*Raad*,' which means 'Thunder,' and the modern Egyptians are totally ignorant of the *cause* of its peculiar power; and if this name was borrowed (as there is every reason to suppose it was) from their predecessors, the question which naturally arises is, were they acquainted with electricity? Had some old Egyptian of the past anticipated by several thousands of years the discoveries of Benjamin Franklin?

There is no answer to this and a hundred other similar questions, which naturally arise in the mind of the student when perusing these records of the past. If we once allow speculation and conjecture to become rife, there is no limit to the knowledge which we can picture the Egyptian of old time to have possessed. So far as the evidence goes—and so far and no further can we go in this volume — the amount of natural philosophy possessed by the ancient Egyptians was entirely practical, founded upon, and like everything else in the first instance, the result of experience.

§ 10. It was reserved for the Greeks (versed in Egyptian and Chaldean knowledge) to pass from sense, perception and calculation to pure reasoning, to examine into the principles of things, and investigate the practical results of the ancient Egyptians in an immaterial and intellectual manner. And they were, both by habit and character, well fitted for the task assigned to them in the evolution of science amongst mankind. 'They who will,' as a writer has observed, 'adopt from others the most beautiful forms, it is doubtful if they have invented any of themselves. But they seek the cause (or rather, perhaps, "laws") of that beauty, they reduce it to rule by analysis and reasoning, they add or take away, improve that which they have borrowed, or so changed in the process to which it is subjected, that it is no longer recognised as the same thing. That which would appear to be natural to the one would seem to be the result of profound thought and inquiry in the other. Let the untaught man of this race (*i.e.*, the Indo-European) model a vase or address his fellows; he produces the rudest and most barbarous forms, or while speaking, roughly and without ease, makes use of the grossest images.' This statement of Layard's is no doubt, broadly speaking, correct; only, let a man of the Indo-European race *be* taught, and that very power of reasoning and analysis which he possesses, that very power of seeking the laws and principles of things which appears to be as innate in him as does 'a brilliant imagination, a ready conception, and a repugnance of all restraints that may affect the liberty of his person,' appear to be in the other; gives him, in the long run, an immense superiority over his rival. Consider, for example, how different has been man's progress since he has investigated phenomena in order to understand their *laws* and the *principles* upon which they depend. From the labours of Galileo and Kepler, and the sublime genius of Newton, have proceeded more light than the labours of a thousand years preceding had been able to produce. The true theory of the movements of the heavenly bodies, the law which regulates the motion of bodies, *i.e.*, *gravitation*, has become the parent of innumerable other discoveries. Navigation, chemistry, mathematics, natural philosophy, and, in consequence, commerce and industry, immediately felt its influence, and every individual of our species has derived, and will continue to derive, so long as mankind exists upon this earth, incalculable benefit therefrom, both intellectual and material.

The modern scientist never forgets, however, that his discoveries are founded upon those of the ancient Egyptians (and Chaldeans), and seeing the extreme care and the marvellous pains taken by these scientists of old to orient their pyramids, and beholding, as he does, the indomitable energy with which they overcame every obstacle, he recognises in them a fellow-worker, and says with the poet,—

> ‘I am as old as Egypt to myself,
> Brother to them that squared the pyramids;
> By the same stars I watch.’

‘ WHY was it that civilisation arose on the banks of the Nile, and not upon those of the Danube and Mississippi? Civilisation depends on climate and agriculture. In Egypt the harvests may ordinarily be foretold and controlled. Of few other parts of the world can the same be said. In most countries the cultivation of the soil is uncertain. . . . The labour of the farmer is at the mercy of the winds and clouds . . . (In Egypt). Man is not the sport of the seasons (and) . . . he need have no anxieties for his future well-being—a country in which the sunshine and heat vary very little from year to year. Agriculture is certain in Egypt, and there man became first civilised. The date tree, moreover, furnishes to Africa a food almost without expense. The climate renders it necessary to use, for the most part, a vegetable diet; and but little clothing is required. The American counterpart of Egypt in this physical condition is Peru, the coast of which is also a rainless district. Peru is the Egypt of civilisation of the western continent. There is also a rainless strand on the Pacific coast of Mexico. It is an incident full of meaning in the history of human progress, that, in regions far apart, civilisation thus commenced in rainless countries.’—J. W. DRAPER.

CHAPTER VII.

THE ORIGIN AND GROWTH OF THE EGYPTIAN SCIENCES.

> 'A thirst after knowledge is perhaps one of the most potent instincts of human nature.'—SIR ERASMUS WILSON.

§ 1. THE question which naturally arises in the mind of the student, after a perusal of the scientific attainments of the ancient Egyptians is, I think, as follows:—Was this culture all their own? Did they or did they not borrow from some surrounding nations, or from some anterior people? This question is by no means a new one. The contest as to the priority of the ancient Egyptians and Chaldeans in such matters as magical science, etc., was hotly contested even in the classic ages of Greece and Rome. Which contest shows, apart from anything else, how ancient civilisation must have been amongst both nations. A half, or even a quarter of a century ago, there was no satisfactory answer to this and similar questions; now, however, there are grounds —many grounds—for concluding that science (by science meaning astronomy and mathematics, *i.e.*, arithmetic) had not its origin amongst this people, but was of exotic growth.

§ 2. First, then, with regard to the subject of astronomy. With regard to this subject, there has practically always been one opinion held—by those competent to hold an opinion — on the subject. Without doubt the Egyptians, in very ancient times, acquired of themselves some ideas in primitive astronomy. They (like the early Greeks and pastoral Italians, and the Chinese and Aztecs) had some native constellation figures. But their zodiac and more advanced ideas on the subject of astronomy were borrowed from their neighbours, the Chaldeans, the greatest astronomers of antiquity. All that we learn from Herodotus and Manetho, and all the evidence of the pyramid kings, corroborate the fact that Egyptian astronomy was derived from the Chaldeans. And the argument derivable from astrology (which was in those days identified with astronomy) tends strongly to support this view; for the whole system of astrology is so peculiar and artificial, that it must of necessity be ascribed to one nation, and the Egyptians themselves admitted the superiority of the Chaldean astrologers, and the common consent of all eastern nations accorded with this view; and lastly, 'the Egyptian claim to the invention of astronomy is not justified by the latest discoveries of Egyptologists; and all the latest classical "authorities" in her favour do not prove that Egypt studied the stars for herself without the assistance of the Chaldeans.'

§ 3. With regard to the origin of mathematics, the only remains of this science that the ancient Egyptians have left us is contained, as we have seen, in a papyrus written in the reign of one of the famous 'shepherd kings;' and the original from which it is copied, according to Dr Birch, dates back to about 3400 B.C., *i.e.*, to the

Note.—Another argument in favour of the Chaldean origin of astronomy and astrology is derivable from the fact that the system of astronomy taught in Egypt, Babylon, Persepolis, etc., does not correspond with the *latitudes* of these places. This argument I have fully considered in my 'Chaldean Science,' pp. 70, 71, and it need not detain us here.

epoch of the building of the Pyramids of Ghizeh, or to a period when we know foreign 'shepherd princes,' etc., were constantly coming into Egypt. Who these shepherds were, and to what race they belonged, is a difficult question to answer. All the evidence of Herodotus and Manetho, however, tends to show that they were Chaldeans, who were in all probability the builders, *i.e.*, as far as its mathematical and astronomical relations are concerned, of the famous Great Pyramid.

From the very earliest times a frequent and close intercourse existed between these two nations. The Egyptian pyramid of Kochome, near Sakkara, which actually dates from the first Egyptian dynasty, is built in steps like the seven-storied Chaldean towers, and that this pyramid of Kochome was originally seven-storied has now, I believe, been established beyond doubt. And, in addition to this, Mr Petrie has pointed out that the scale marked on a plan in the lap of one of the statues from Tell-Ho (which some recent French excavations have unearthed) agrees with that used in Egypt in the age of the pyramid builders. It is difficult, therefore, to avoid the conclusion, 'that, as early as the fourth Egyptian dynasty, an Egyptian (?) school of sculptuary existed amongst the quarries of Sinai, which transported its works to Memphis on one side, and the land of the ancient Chaldeans on the other.' And we now know (owing to the recent discovery of some cuneiform tablets at Amarna, in Upper Egypt) that there was an active literary correspondence from one end of the civilised East to the other, as early, at any rate, as the eighteenth Egyptian dynasty, *the medium of the literary correspondence being the Babylonian language correctly written*—thus showing that the Egyptian scribes had acquired a very thorough knowledge of the complicated cuneiform syllabary. And it is also evident from this valuable discovery, that good schools existed throughout Western Asia, and also in Egypt, and that the study of the cuneiform language of the Chaldeans was one which engaged their careful attention.

§ 4. This and other discoveries have, of course, once and for all settled the difficult question as to the independent advancement in learning of these two nations, clearly showing that one borrowed from the other, and *vice versa.* As to their priority in science, the Chaldeans appear to have the prior claim; in astronomy they most certainly have, and with regard to the question of mathematics, though the evidence is not so positive, it points in certain instances the same way. *Plane Geometry*, or the geometry of areas and angles, was probably, as we have already pointed out, of Egyptian origin; *arithmetic* (at any rate, the *duodecimal* and sexagesimal methods) of Chaldean origin, from whom, in all probability, originated much of the *Spherical Geometry* which is found in certain later Greek writers.

§ 5. With regard to the other sciences—of medicine, chemistry, engineering and natural philosophy — there is little or no evidence. Most, or at any rate many, of the Egyptian mechanical inventions first appear to have been used by the ancient Egyptians at a time when a temporary closer intimacy existed between them and the Assyrians or Chaldeans. Much of the learning of the ancient Egyptians was probably of exotic growth; in their engineering triumphs, however, they stand quite alone.

§ 6. Why the ancient Egyptians observed the courses of the stars, built vast pyramids and immense canals and artificial lakes, and created monuments which no one can behold without a sense of awe and admiration, is not in itself a difficult question to answer. Egypt both is and was a land of tranquil monotony; there is in it an entire absence of picturesque scenery. A single mighty river, unbroken within the limits of Egypt even by a single rapid, two flat strips of green plain on either side, two low lines of straight-topped hills beyond them, and a boundless open space, where the river divides itself into half-a-dozen sluggish tributaries reaching the sea. Such is and was Egypt; by nature a kind of Oriental Holland—'weary, stale, flat and unprofitable.' Where Nature is most tame and commonplace, there we always find that man has done his utmost to overcome this sameness, and is there tempted to his flights of highest audacity. As upon the level plains of Chaldea he attempted to build a tower that should 'reach unto the heavens,' so in Egypt he strove to accomplish gigantic works, enormous undertakings and mighty enterprises, which would appear at first sight to have been wholly beyond his power. It has been observed that 'Egypt was the gift of the Nile,' a saying which is true in more ways than one. To the annual inundations of this river we owe, in all probability, as we have already pointed out, the origin of geometry and certain portions of the science of engineering, and much of the sciences of mechanics and hydrostatics. And the level Egyptian plains—uninterrupted by a single eminence, with a sky seldom overshadowed by a passing cloud—were a fit place for the study of astronomy, a subject which would naturally engage the attention of the hunter and the shepherd long before it became the study of the priest and the philosopher.

§ 7. The use of iron, and even tempered steel, as well as of bronze, in the land of Egypt, seems to go back as far as historical record reaches. Chipped flints, too, apparently belonging to a Pre-historic Stone Age, are picked up plentifully there; while the sharp stones or stone knives used by the embalmers appear to indicate an earlier time, when these were the cutting instruments in common use. There are, therefore, signs that a Stone Age preceded a Metal Age in Egypt as elsewhere; and the high antiquity of the use of metal only throws back to a still higher antiquity the use of stone. And, if we accept the authority of Diodorus and Clemens of Alexandria, we are able to assert that the famous books or papyri, attributed by the Egyptians to Hermes, which were supposed by them to contain the philosophy and science of the ancient Egyptians, all date before the reign of Menes. The *original* work, by whomsoever it was compiled, was, no doubt,

Note.—Nothing, I think, asserts the antiquity of Egyptian civilisation with so much force as the results obtained from an examination, made by Mr Horner at Heliopolis, concerning the annual mud deposit of the Nile, which he (after the most accurate measurements) estimated at 3·18 inches. The Colosses of Rameses II. is surrounded by a sediment 9 feet 4 inches deep. Its date of erection was about 3125 years ago, which gives 3½ inches a century. But beneath it similar layers continued, to a depth of 40 feet, and even beyond. This, at the same rate, gives a period of 13,700 years. *From the greatest depth fragments of pottery were obtained.*

very crude and imperfect; and these famous books of Hermes were not, of course, written by one person, nor yet at one period. Nor was Toth, Hermes or Mercury a real personage, but a deified form of the divine intellect, which, being imparted to man, had thereby enabled him to produce these efforts of genius. The chief argument in favour of the high *antiquity* of the work—which chiefly concerns us here—is the tradition of the people, already alluded to (supported as it is by the astronomical, mathematical and engineering skill of the pyramid builders), to the change effected by him in the course of the Nile.

§ 8. The question which this high antiquity of science amongst the ancient Egyptians naturally suggests is, How is it that a people like the Egyptians, who possessed at so remote a period so much knowledge with regard to observational and practical science, were not led on in course of time to other discoveries, and to the foundation of a science upon a theoretical basis? Even the ancients themselves, who were indebted to the Egyptians for the rudiments of so many sciences, observed with surprise that they made no further progress in them. This question has already received a partial answer in these pages. The chief reason was, no doubt, the obstinate conventionalism and conservatism of the Egyptian priests, who in later times had a monopoly of both the arts and sciences in Egypt, and who were the absolute slaves of tradition, and who appear to have been either too frightened or too lazy to alter the rules or extend the knowledge of their craft. Concerning their medicine, we have already called the reader's attention to the statement of Diodorus, that 'the Egyptian doctors used only the prescriptions contained in the most ancient sacred books, lest they should be accused of manslaughter in case the patient died.' The other sciences appear to have been treated with a similar timidity. Any kind of progress under such circumstances as these was, of course, an impossibility; for little change and no progress are, we know, synonymous terms. It is probable, however, as I hope to show in the next part of this work, that the Egyptians of the Alexandrian school, educated in Greek learning, made some important additions to Greek mathematics, and that it is the Egyptians of this school to whom we are indebted for our present sciences of trigonometry and algebra.

PART II.

‘THE Alexandrian school soon assumed the character of a University. In it those great libraries were collected, the pride and boast of antiquity. Astronomical observatories, chemical laboratories, libraries, dissecting houses were not in vain. There went forth from them a spirit powerful enough to tincture all future times. Nothing like the Alexandrian Museum was called into existence in Greece and Rome, even in their palmiest days. It is the unique and noble memorial of the dynasty of the Ptolemies, who have thereby laid the whole human race under obligations, and vindicated their title to be regarded as a most illustrious race of kings. . . . Though, in the night through which Europe has been passing, men have not entertained a right estimate of the spirit in which that great institution was founded, and the work it accomplished, . . . the time is approaching when its action on the course of human events will be better understood, and its influences on European civilisation more clearly discerned.’—J. W. DRAPER.

CHAPTER I.

THE ALEXANDRIAN SCHOOL.

> 'Under the shadow of the pyramids, Greek philosophy was born; after many wanderings for a thousand years around the shores of the Mediterranean, it came to its native place, and under the shadow of the pyramids it died.'—DRAPER.

§ 1. IT is an Egyptian city that can first lay claim to the title of a 'University,' to which all the world might come and be instructed in the then existing knowledge. Its name is Alexandria, founded B.C. 332 by Alexander the Great, when he turned from the land of Palestine into Egypt. To the sovereignty of this magnificent city Ptolemy, the son of Lagus, succeeded on the division of Alexander's empire after his death. Ptolemy was a man who had imbibed much of Alexander's enthusiasm, and he it was who created the famous

University of Alexandria,[1] whose buildings stood near the palace, and were provided with lecture-rooms, laboratories, museums, a zoological garden, walks, promenades and other accommodations, all clustered round the great library, which contained, in the time of Ptolemy Philadelphus (*cir.* B.C. 260), 400,000 rolls,[2] which represented 90,000 distinct works; and there was, in addition to this, another library in the Egyptian quarter of the city, which is said to have contained 40,000 works. Criticism, medicine, mathematics, geography, natural history, astronomy, chemistry, natural philosophy and jurisprudence were for nearly a thousand years taught in her schools; no wonder is it, therefore, that we owe to this same University of Alexandria all that is best in the sciences of antiquity. A distinguished Athenian, Demetrius Phalereus, was invited to take charge of the library, and it is probable that the immortal Euclid was invited with him to open the mathematical school. It is in this university that the most famous of the Greek geometers taught and studied, and in later years Greek and Egyptian there worked together, and that is why it is so difficult to assign the work done by each people. Formerly it was the custom to attribute exclusively to the Greeks the works of this school, just as it was the custom to attribute to them the origin of all science and art. Whereas we now know that the Greeks were only the progressors of those arts and sciences which they did not invent, they being to the Egyptians very much what the Moors and Arabs of the Middle Ages were to Europe; and it is precisely because the Greeks were not the creators of these sciences that they were able to make such progress in one of them, viz., geometry.

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[1] It is said that at one time no less than 14,000 students were assembled there.

[2] The library of Oxford, in the year 1300 A.D., consisted of a few *tracts*, kept in chests.

§ 2. Before considering the labours and discoveries of the Alexandrian school, let us briefly relate what advances the Greeks themselves had made in the sciences between the time when the Egyptian king, Psammetik (B.C. 650, *cir.*), first opened the ports of Egypt to strangers, which had formerly always remained closed, *i.e.*, from the time when Greek travellers and merchants first journeyed to the land of the Pharaohs to the time of the founding of the famous Alexandrian Library (B.C. 300, *cir.*). The Greek philosopher, Thales, introduced the sciences of the ancient Egyptians in Ionia about 580 B.C. Pythagoras introduced them in Magna Graecia about 530 B.C. In these places, the extreme eastern and western limits of Hellas, scientific schools survived for nearly 200 years, but the Ionian, the one founded by Thales, was by far the less meritorious of the two. To the former we appear to owe much of Euclid's first book, some very elementary ideas on the subject of astronomy, a little elementary arithmetic, and what is usually described as the origin of electricity.

To the latter we owe, no doubt, Euclid's second book, the foundations of the fourth, fifth and sixth books, and the foundation of geometry upon a theoretical basis, for it is expressly stated (in the Eudemian summary of early Greek mathematics) that he[1] changed the study of geometry into the form of a liberal education, for he examined its principles to the bottom, and investigated its theories in an immaterial and intellectual manner. Diogenes Laertius states, on the authority of Favorinus, that Pythogoras 'used definitions on account of the mathematical nature of his subject.' This was, in all probability, the first great step towards that systematisation of geometry so successfully carried out by the later Greeks. To this school we also owe much of that inexhaustible fertility in giving the most varied interpretation of half-perceived facts, both with regard to astronomy and natural philosophy, for which the Greeks have always been so distinguished. This school also devoted itself a great deal to the theory of numbers, or *arithmetica*, but made no progress of importance in the science.

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[1] *i.e.*, Pythagoras.

Before these schools were altogether extinct, the Sophists, about 450 B.C., introduced geometry at Athens, where, under the stimulus of those three famous problems, the Quadrature of the Circle, the Trisection of any Angle, and the Duplication of the Cube, arose the geometry of the circle and other curves (chiefly with Hippias and Hippocrates), and still later the geometry of the Conic Sections in particular, and of *loci*, stereometry, and (though in a much lesser degree) natural philosophy and astronomy. The *principal* advance made in the sciences during this period was, of course, the establishment of geometry on a theoretical basis.

§ 3. The three most famous scientists of the Greek students of the Alexandrian school were Euclid, Appolonius and Archimedes, the three greatest mathematicians of antiquity.

To the first we are indebted for the 'Elements of Euclid,' that book which embodies and systematises the truest results of the search after truth that was made by Chaldean, Greek and Egyptian. It was the first Greek book translated into the Arabic language. It went into exile with the other sciences of the ancients during the Middle Ages, along with the intellectual activity and goodness of Europe. It was studied, and taught, illustrated and commented upon by the Arab at the University of Bagdad, and on the burning plains of Arabia; by the Nestorian in the sunny city of Cordova, and by the Moor in his Alhambraic palaces. From these it was brought back into semi-barbaric Europe by Jewish pedlars and terrified students, who dared scarcely relate the things which they had learnt amongst the Moors and Saracens. Translated at length from Arabic into Latin, it passed into the schools of Europe, and thence, after being translated into the various languages of Europe, it was the foundation stone upon which all modern mathematicians based their great discoveries.

§ 4. To the second and third of these three great Greek mathematicians we owe 'The Sphere and Cylinder,' and 'The Conics'—two works on geometry ranking only next to the 'Elements' of Euclid. 'The works of Archimedes and Appolonius,' says M. Chasles, 'mark the most brilliant period of ancient (theoretical) geometry. They may be regarded, moreover, as the origin and foundation of two questions which have occupied geometers at all periods. The greater part of their works are connected with these, and are divided by them into two classes, so that they seem to share between them the domain of geometry.

The first of those two great questions is the quadrature of curvilinear figures, which gave birth to the calculus of the infinite, conceived and brought to such perfection by Kepler, Cavalieri, Fermat, Leibnitz and Newton. The second is the theory of conic sections, for which there were invented—first, the geometrical analysis of the ancients—afterwards the methods of perspective and transversals. This was the prelude to the theory of geometrical curves of all degrees, and to that considerable portion of geometry which considers in the general properties of extension only the forms and situations of figures and uses, only the intersections of lines or surfaces, and the ratios of rectilinear distances.'

§ 5. I have devoted thus much space to the subject of geometry, because it was in this subject that the Greeks so particularly excelled. The advances made by them in the other sciences, with the exception of the mechanical and hydrostatical discoveries of Archimedes[1] are inconsiderable. 'Ordinary Greek calculation' (*i.e.*, arithmetic), says Mr Gow ('Short History of Greek Mathematics'), 'remained to the last so clumsy and primitive, that if any progress in the art is to be ascribed to the Greeks, it can be exhibited only by going back to the beginning.' 'Of the performance of the Greeks in arithmetic,' says Hankel, 'our judgment may be shortly stated thus: they are in form and contents unimportant, childish even; and yet they are not the first steps which science takes, as yet ignorant of her aim, tottering upon shaky ground. . . . It is a dotage without a future, which wearies us in these writings. With regard to their astronomy, the Greeks did little for this science, save Hipparchus (161-127 B.C.), from whose writings the 'Almagest'[1] of Ptolemy is clearly almost entirely derived. And in spite of the fact that so much has been written about the proficiency of the Greeks in astronomy, it

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[1] It should, however, always be most carefully remembered that Archimedes was the intimate friend of Conon of Alexandria, and connected with the Alexandrian school in many ways. The famous Archimedean *screw* was intended for

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raising the waters of the Nile. There appears to be, however, considerable doubt as to whether he was really the *inventor* of it.

[1] For a brief description of the famous 'Almagest,' see the note at the end of this chapter. Ptolemy was also the author of a work on geography, used in European schools as late as the fifteenth century.

is an open question if the astronomical knowledge possessed by the Chaldeans (the greatest astronomers of antiquity), during or even long before the days of Terah and Abraham, was not much more accurate than that possessed by the Greeks even in or after the time of Hipparchus,[1] for although he had the immense advantage of being able to compare his own observations with those recorded by the Chaldeans, he estimated the length of the year less correctly than they. As observational astronomers, the Greeks were, we know, never celebrated; they certainly did evince an inexhaustible fertility in giving the most varied interpretations of half-perceived facts, but this tends rather to retard than advance science.[2]

§ 6. Turning now to the Egyptian scientists of the Alexandrian school, the most famous—and, indeed, the only ones concerning which we possess any positive knowledge — are Diophantus, Heron and Ptolemy (the author of the 'Almagest'). It is in the works of this famous Heron (120-100 B.C.) that the first signs of trigonometry and algebra appear. In those of Diophantus (*cir.* 360 A.D.), an algebraic symbolism first appears; and his famous 'Arithmetica' is probably the first treatise on algebra ever written; at any rate, it is by far the oldest now extant. Diophantus' symbols are not Greek, but they probably *were* Egyptian. Both Heron and Diophantus were Alexandrians. Now, all this evidence tends to show that both trigonometry and algebra are of Egyptian origin. Proclus speaks of '*οι περι Ηρωνα*' as if Heron founded a school. There are, of course, large gaps in the history of the Alexandrian mathematical school. And 'it is not an improbable supposition,' says Mr Gow, 'that there were, in Alexandria and Pergamum and elsewhere, as in the English Universities at the present day, many mathematicians of great ability and inventiveness who did not write books, but were content to allow their knowledge to ooze out in lectures and private communications. What little evidence there is, and the absence of more, suggest that these mathematicians were of Semitic or Egyptian origin.'

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[1] *Vide* the Author's 'Our Debt to the Past,' pp. 12-36.

[2] Chemistry owes nothing or next to nothing to the Greeks. Of their medicine, I have already made mention in Part I., Chapter III., § 7.

§ 7. In the writings of the Alexandrian mathematical and astronomical school, two classes of mathematical and astronomical writers are at once apparent. The first (the Greek) studied the science of mathematics in order that he might 'habituate the mind to the contemplation of pure truth, and raise himself above the material universe.' The science of astronomy was valuable to him only 'as raising the mind to the contemplation of things which are to be perceived by the pure intellect alone, and not as adding to the vulgar comforts of life.' With regard to natural philosophy, the Greeks held the same opinions; even Archimedes himself held the then prevailing opinion that geometry was degraded by being applied to anything useful. And he with difficulty could be induced to stoop from speculation to practice. He was half-ashamed of his marvellous mechanical inventions, which were the admiration of all foreign nations, and always spoke of them slightingly, as trifles, in which a mathematician might, without much disgrace, indulge after intense application to the higher branches of his science.

§ 8. The second (the Egyptian or Semitic) entertained, in the main, very different views from these. The science of mathematics was studied by them in order that they might—(1) Find the difference of level between two points; (2) buy and sell with greater advantage; (3) measure a field without entering it; (4) ascertain the distance of the sun and moon; (5) determine the diameter and circumference of the earth; (6) ascertain the longitude and latitude of a place, etc., etc. And natural philosophy, in order that they might invent—(1) fire-engines; (2) a self-trimming lamp; (3) a water-clock; (4) a new kind of cupping-glass; (5) more perfect hydraulic machines; (6) catapults, etc.[1] The first studied science that they might learn to 'withdraw their minds from the ever-shifting spectacle of this visible and tangible world, and fix them on the immutable essence of things.'—(PLATO). The second, that they might facilitate intercourse and business matters, that they might excavate canals and build bridges; that they might furnish new arms to the soldier, and new security to the warrior; that they might facilitate motion, annihilate distance, and strengthen human endeavour. The endeavour of the first was, as has been truly said, 'to exalt man into a god.' The endeavour of the second was to make this life on earth more blessed, less accursed. The aim of the first was noble, but impracticable, and therefore failed; the aim of the second was more sordid (some will no doubt say), but it was practical, and therefore succeeded. 'The philosophy of the first began in words and ended in words—noble words, we grant, but still only words; that of the second began in observation and experiment, and ended in science and art.'

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[1] *Vide* the works of Heron, Diophantus, Ptolemy, etc.

§ 9. What we owe to the *Egyptians* of the Alexandrian school appears, then, to be this—that they detached science from the ideal moorings of the Platonic school, and started it on its career of conquest over the whole world of phenomena—a debt which cannot be over-estimated.

§ 10. The sciences of the Egyptians and

Greeks passed over in the ninth century of our era to the Arabs, Moors and Hindoos, and were then studied in the Arabian university of Bagdad, in the Nestorian schools of Cordova, and the Hindu pagodas and temples of Northern India. But little advances were made by them in the sciences, save with respect to the symbolisms of algebra and trigonometry, and the invention (usually ascribed to some unknown Hindu of uncertain date) of our present simple but grand arithmetical notation—an invention which, for practical utility and usefulness, has probably never been surpassed, giving man, as it did, a power over numbers hitherto undreamt of and unimagined. We must always remember, however, that they kept the sciences of the ancients alive, and even infused a new life into some of them,[1] at a time when we Europeans were occupied almost solely in pursuit of our fellow men; being far more occupied at that time with our conquests over matter than over mind. Brought back into Europe by Jewish pedlars and students, too terrified almost to relate what they had learnt in their sojourns among foreign nations, for fear lest the bigotry and superstitions of those days should burn them as wizards, or break them on the wheel for having had relations with the Evil One, the sciences of the ancients at last found a haven and a refuge in the universities of modern Europe, and were the means by which Kepler, Galilio, Copernicus and Newton achieved their immortal discoveries, and caused the dawn of modern science to break triumphant on the world.

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[1] Chemistry and astronomy, for instance.

NOTE ON 'THE ALMAGEST' OF PTOLEMY.

The following is a brief description of that famous work which represents the astronomical knowledge of the Alexandrian school. Its starting point is the doctrine that the earth is globular, and fixed in space, round which the sun, moon, stars and planets revolve. It contains descriptions of the construction of a table of chords, and instruments for observing the solstices and deductions relating to the obliquity of the ecliptic. In it terrestrial latitudes are found by means of the gnomon; it contains descriptions of different climates, and calculations showing how ordinary time may be converted into sidereal time, giving reasons for preferring the tropical to the sidereal year; furnishing the solar theory on the principle of the sun's orbit being a simple eccentric; it explains the equation of time, and advances and discusses the motions of the moon, treating of the first inequality of her eclipses, and the motion of the mode. Then giving Ptolemy's own great discovery—the discovery of the moon's erection, or second inequality, reducing it to the epicyclic theory. In it are attempts at the determination of the distances of the sun and moon, with only partial success, however—the sun's distance being made but one-twentieth of the real amount. It deals with the precession of the equinoxes—the discovery of the Chaldeans; it gives a catalogue of 1022 stars, treats of the nature of the Milky Way, and discusses in a most masterly manner—though we now know it to be an erroneous one—the motions ot the planets.—Ptolemy's 'Immortal Systems of Cycles and Epicycles.'

NOTE ON MEDICINE IN THE UNIVERSITY OF ALEXANDRIA.

The earliest and most famous physicians of this school were Cleombrotus, Herophilus and Erasistratus, and among the subordinate physicians was Philo-Stephanus, who had charge of natural history, and was directed to write a book on fishes. The Alexandrian school was founded upon the sure and certain basis of *Anatomy*. The physicians were authorised by the royal authority of Ptolemy to resort to the dissection of the dead, and to ascertain, by that only trustworthy method, the correct structure of the human body. They were, in addition, authorised to make vivisections, both of animals, and also of criminals who had been condemned to death, in order that they might ascertain the mode in which the functions are carried forward, and the manner in which they work. Herophilus wrote a treatise on the practice of medicine, on obstetrics, on the eye, on the pulse in which he correctly referred to the movements of the heart. He was aware of the existence of the lacteals, and their anatomical relations to their mesenteric glands.

Erasistratus, his colleague, a pupil of Theophrasites and Chrysippus, describes the nature of the heart, its connections with the veins and arteries, but falls into the mistake that the veins were for the conveyance of air, and the arteries for that of blood. He knew that there were two kinds of nerves—those of motion and those of sensation. Of course, under such circumstances as these, the departments of surgery and pharmacy received many improvements, and produced, no doubt, many (unknown) able men.

Amongst the improvements in surgery effected by this school may be mentioned new operations for lithotomy, instruments for crushing the calculi, for reducing dislocations, etc. The memorable Galen (130 A.D.) was also a student at this school.

The debt which the modern science of medicine owes to this same University of Alexandria can scarcely be overrated.

THE PAST.

THOU unrelenting Past!
  Strong are the barriers round thy dark domain
And fetters sure and fast,
  Hold all that enter thy unbreathing reign.

Far in thy realm withdrawn
  Old Empires sit in sullenness and gloom,
And glorious ages gone
  Lie deep within the shadow of thy womb.

Full many a mighty name
  Lurks in thy depths, unuttered, unrevered;
With thee are silent fame,
  Forgotten arts, and wisdom disappeared.

Thine for a space are they—
  Yet shalt thou yield thy treasures up at last;
Thy gates shall yet give way,
  Thy bolts shall fall, inexorable Past!

BRYANT.

CHAPTER II.

CONCLUDING REMARKS.

> 'The hours should be instructed by the ages, and the ages explained by the hours.'—R. W. EMERSON.

§ 1. AFTER the foregoing matter of this book, it may be, I think, truly said that the ancients knew many things, though they were ignorant of the general laws that governed them. They possessed, indeed, some general ideas, true flashes of genius—for they saw that there must be general laws to which the universe conformed, and of which they had occasional glimpses—through the distortion of an imperfect vision, it is true, and which were in those early days too wide in their grasp, and connected by links too shadowy to be apprehended by most minds. With their knowledge we have, as the reader has seen, only an imperfect acquaintance, chiefly by means of the inadequate and imperfect representations of later writers; but we must carefully remember, as Professor Spottiswoode has pointed out, 'that *to* the existence of such ideas is due not only the conception, but even the *possibility* of a physical science.'

§ 2. To correctly understand the chronological difference in the origin and development of the different sciences, we must bear in mind that this universe is in itself but one great whole, but though it be but one, man, with his limited intelligence, is unable to regard it as such, but is obliged to push his investigations when and where he can. Thus have arisen many sciences —at first, of course, quite isolated—seemingly without relation. Their separate existence at any epoch is a mark of the feebleness of the powers of human investigations existing at that epoch. Their general convergence, and especially when any complete compact can be established between them, is a certain mark of the advancing knowledge of the times. The less complicated would, of course, at first naturally arise. In mathematics and physical science, many difficulties stand aside out of our path, because we are not embarrassed by that most wonderful but perplexing phenomenon of life. Those first arose, therefore, in which there was no great difficulty about the fundamental data, *i.e.*, those of mathematics and physics (in which much valuable progress can be made by the mathematician, the student of the deductive method) and chemistry (in which similar progress can be made by the experimentalist). The physical sciences, therefore, as we have seen, naturally had their birth before those sciences investing the phenomena of consciousness, or the biological sciences, and those sciences relating to mental phenomena. In the domain of the physical sciences, the phenomenon of life is wanting, and it is here that the mind of man was *first* able to cope with the realities of the universe, and in which his greatest achievements have been made. But the reader must remember that it has taxed to the utmost the reasoning powers of understandings like Newton's to evolve the few consequences that we already know, and the investigator has had to call to his assistance every aid to prolonged consecutive thought which mathematicians could devise; and, above all, it has required the patient labours and gradually increasing discoveries of thousands and thousands of years.

§ 3. In forming their ideas of the origin of things, our earliest historic and pre-historic ancestors relied, like ourselves, upon experience, only the experience relied upon by them was not derived from the study of nature, but from that of man. 'Their theories took,' as Professor Tyndall has observed, 'an anthropomorphic form.' To supernatural beings, which, 'however potent and invisible, were nothing but a species of human creatures, perhaps raised from among mankind, and retaining all human passions and appetites,'[1] were handed over the rule and governance of natural phenomena. In course of time these ideas failed, of necessity, to satisfy the more penetrating and curious intellects of our ancestors.

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[1] Hume.

Thus far back in the past, anterior even to all history, we find men separating themselves from their fellow-men, and rejecting their anthropomorphic ideas, and endeavouring 'to connect natural phenomena with physical principles.' They are, it is true, UNKNOWN; of the lives of most of them we know nothing. That need not prevent us, however, from honouring their unknown names, even as we honour the names of Euclid, of Ptolemy, and of Newton.

In conclusion, then, I think the slowly crumbling relics of the dead and bygone ages must ever arouse within us all that is left of sympathy and wonder. Let us not forget what our present civilisation owes to the Egyptian of old time. Egypt, unique in her glory as in her desolation, has unrobed herself in all her marvellous works, fascinating us with the magic of her ageless triumphs. And ever and anon she will still yield to our patient search some tokens, not of mummy dust or rock-hewn, stone-built tomb or temple erected to the selfish pride of her kings, or the majesty of her gods, but of human interests and pursuits, which unite us all down through the thousands of years of man's strange, eventful history in bonds of kindred sympathy.

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